

VE280 Programming and Elementary Data Structures

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Operator Overloading

MY NEW LANGUAGE IS GREAT, BUT IT
HAS A FEW QUIRKS REGARDING TYPE:

```
[1] > 2 + "2"  
=> "4"  
[2] > "2" + []  
=> "[2]"  
[3] > (2/0)  
=> NaN  
[4] > (2/0)+2  
=> NaN  
[5] > "" + ""  
=> " + "  
[6] > [1,2,3]+2  
=> FALSE  
[7] > [1,2,3]+4  
=> TRUE
```

```
[8] > 2/(2-(3/2+1/2))  
=> NaN.00000000000000013  
[9] > RANGE(" ")  
=> (' ', '!', ' ', ' ', '!', ' ')  
[10] > + 2  
=> 12  
[11] > 2+2  
=> DONE  
[14] > RANGE(1, 5)  
=> (1, 4, 3, 4, 5)  
[13] > FLOOR(10.5)  
=> |  
=> |  
=> |  
=> |__10.5__|
```

Learning Objectives

- Review and master operator overloading.
- Understand what is friendship.
- Study some examples of operator overloading, e.g., $+$, $+=$, $[]$, $<<$, $>>$.

Operator Overloading

Introduction

- C++ lets us **redefine** the meaning of the operators when applied to objects of **class type**.
- This is known as **operator overloading**.
- Which operator have we overloaded before? Why?
- Operator overloading makes programs much easier to write and read:

```
IntSet is;  
int x = is[5]; // overload [] operator  
           // access the IntSet element by index  
cout << is << endl; // overload << operator  
           // print all the IntSet elements
```

Operator Overloading

Basics

- Overloaded operators are functions with special names: the keyword **operator** followed by the symbol (e.g., +, -, etc.) of the operator being redefined.
- Like any other function, an overloaded operator has a return type and a parameter list.

```
A operator+(const A &l, const A &r) ;
```

Operator Overloading

Basics

- Most overloaded operators may be defined as ordinary **nonmember** functions or as class **member** functions.

```
A operator+(const A &l, const A &r);  
// returns l "+" r
```

```
A A::operator+(const A &r);  
// returns *this "+" r
```

- Overloaded functions that are members of a class may appear to have **one fewer** parameter than the number of operands.
 - Operators that are member functions have an implicit **this** parameter that is bound to the **first operand**.

Operator Overloading

Basics

- An overloaded **unary** operator has **no** (explicit) parameter if it is a member function and **one** parameter if it is a nonmember function.
- An overloaded **binary** operator would have **one** parameter when defined as a member and **two** parameters when defined as a nonmember function.

Example

- Overload **operator+=** for a class of complex number.

```
class Complex {  
    // OVERVIEW: a complex number class  
    double real;  
    double imag;  
public:  
    Complex(double r=0, double i=0); // Constructor  
    Complex &operator += (const Complex &o);  
    // MODIFIES: this  
    // EFFECTS: adds this complex number with the  
    // complex number o and return a reference  
    // to the current object.  
};
```

Example

```
Complex &Complex::operator += (const Complex &o) {  
    real += o.real;  
    imag += o.imag;  
    return *this;  
}
```


Example

- `operator+=` is a member function.
- We can also define a nonmember function that adds two numbers.

```
Complex operator + (const Complex &o1,  
                  const Complex &o2) {  
    Complex rst;  
    rst.real = o1.real + o2.real;  
    rst.imag = o1.imag + o2.imag;  
    return rst;  
}
```



What's the issue with the non-member version, if any?

```
Complex operator + (const Complex &o1,  
                   const Complex &o2) {  
    Complex rst;  
    rst.real = o1.real + o2.real;  
    rst.imag = o1.imag + o2.imag;  
    return rst;  
}
```

Select the correct answer.

- **A.** There's an extra space between `operator` and `+`.
- **B.** The `const` keyword shouldn't be used here.
- **C.** The code wouldn't compile as is.
- **D.** There's no issue.



Friend

- So, we'll need some other mechanism to make the function as a "**friend**".
- The "friend" declaration allows you to expose the **private** state of one class to another function (and only that function) explicitly.

```
class foo {  
    friend void baz();  
    int f;  
};  
void baz() { ... }
```

The function **baz** has access to **f**, which would otherwise be private to class **foo**.

Friend

- So, we'll need some other mechanism to make the function as a "**friend**".
- The "friend" declaration allows you to expose the **private** state of one class to another function (and only that function) explicitly.

```
class foo {  
    friend void baz();  
    int f;  
};  
void baz() { ... }
```

Note: a friend function is **NOT** a member function; it is an ordinary function.

Note: NOT `void foo::baz() { ... }`

Friend

- So, we'll need some other mechanism to make the function as a "**friend**".
- The "friend" declaration allows you to expose the **private** state of one class to another function (and only that function) explicitly.

```
class foo {  
    friend void baz();  
    int f;  
};  
void baz() { ... }
```

Note: "friend void baz ();" goes inside foo. It means foo gives friendship to function baz ().

Friend

- Besides function, we can also declare a class to be friend.

```
class foo {  
    friend class bar;  
    int f;  
};  
class bar {  
    ...  
};
```

Then, objects of class `bar` can access private member `f` of `foo`.

Friend

```
class foo {  
    friend class bar;  
    friend void baz();  
    int f;  
};  
class bar { ... };  
void baz() { ... }
```

Friendship of both
class and function.

- Note: Although “**friendship**” is declared inside **foo**, **bar** and **baz()** are not members of **foo**!
- “**friend**” declaration may appear anywhere in the class.
 - It is a good idea to **group** friend declarations **together** either at the beginning or end of the class definition.

Example

- In our example of complex number class, we will declare **operator+** as a friend:

```
class Complex {  
    // OVERVIEW: a complex number class  
    double real;  
    double imag;  
public:  
    Complex(double r=0, double i=0);  
    Complex &operator += (const Complex &o);  
    friend Complex operator+(const Complex &o1,  
                             const Complex &o2);  
};
```

Its implementation is the same as before.

Overloading Operator []

- We want to access each individual element in the IntSet through **subscript operator []**, just like how we access an ordinary array.
 - For example, **is[5]** accesses the sixth element in the IntSet **is**.
- We need to overload the **operator []**.
 - It is a binary operator: The first operand is the IntSet object and the second one is the index.

Overloading Operator []

- We write two versions with bound checking

```
const int &IntSet::operator[](int i) const {  
    if(i >= 0 && i < numElts) return elts[i];  
    else throw -1;  
}
```

const version returning a const reference to int

```
int &IntSet::operator[](int i) {  
    if(i >= 0 && i < numElts) return elts[i];  
    else throw -1;  
}
```

nonconst version returning a reference to int

Overloading Operator []

- Why we need a nonconst version that returns a reference to int?
 - We need to assign to an element through subscript operation
`is[5] = 2;`
- Why we need a const version that returns a const reference to int?
 - We may call the subscript operator with some const IntSet objects or within some const member function. Const objects/const member function can only call their const member functions.
 - Furthermore, the return type should be const reference because we cannot use a const object (`elts[i]` in this case is a const int) to initialize a non-const reference.
- Which version is called if both are OK?
 - Answer: the non-const version.

Overloading Output Operator <<

- We want to redefine the **operator<<** for the `IntSet` class, so that it prints all the elements in the set in sequence.
- Convention of the IO library
 - The **operator<<** should take an **ostream&** as its first parameter and a **const** reference to an object of the class type as its second.

```
os << obj;
```

- The **operator<<** should return a reference to its **ostream parameter**.

```
ostream &operator<<(ostream &os, const IntSet &is){  
    ...  
    return os;  
}
```

Overloading Output Operator <<

```
ostream &operator<<(ostream &os, const IntSet &is){  
    ...  
    return os;  
}
```

- Why should **operator<<** return a reference to its **ostream parameter**?
 - Because **operator<<** can be **chained together**:
`cout << "hello " << "world!" << endl;`
 - It is equivalent to
`cout << "hello ";`
`cout << "world!";`
`cout << endl;`

Overloading Output Operator <<

- **operator<<** must be a nonmember function!
 - The first operand is not of the class type.
- We can implement **operator<<** as follows

```
ostream &operator<<(ostream &os, const IntSet &is){  
    for(int i = 0; i < is.size(); i++)  
        os << is[i] << " ";  
    return os;  
}
```

Question: Which version of operator[] is called?

- Now we can write **cout << is << endl;**

Do we need to declare << as a friend of IntSet?



Select the correct statements.

```
ostream &operator<<(ostream &os, const
IntSet &is) {
    for(int i = 0; i < is.size(); i++)
        os << is[i] << " ";
    return os;
}
```

Select all the correct answers.

- **A.** In `is[i]`, the `const` version of operator `[]` is called.
- **B.** In `is[i]`, the non-`const` version of operator `[]` is called.
- **C.** Operator `<<` needs to be friend with `IntSet`.
- **D.** Operator `<<` need not be friend with `IntSet`.



Overloading Input Operator >>

- Convention of the IO library
 - The **operator>>** should take an **istream&** as its first parameter and a **nonconst** reference to a object of the class type as its second.

Question: why nonconst?

```
is >> obj;
```
 - The **operator>>** should return a reference to its **istream parameter**.

Question: why returning reference?

```
istream &operator>>(istream &is, foo &obj){  
    ...  
    return is;  
}
```


Reference

- **C++ Primer (4th Edition)**, by *Stanley Lippman, Josee Lajoie, and Barbara Moo*, Addison Wesley Publishing (2005)
 - Chapter 12.5 **Friends**
 - Chapter 14 **Overloaded Operations and Conversions**