UEE1303
Objective-Oriented Programming

C++_Lecture 06:

Operator Overloading

C: How to Program 8th ed.

Agenda

- Fundamentals of Operator Overloading (chapter 18.3)
- Restrictions on Operator Overloading (chapter 18.3)
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Fundamentals of Operator Overloading

- Operators are overloaded in C/C++
  - `+7, 2+5, 3.25+7.3`
- In addition to overloading, compilers often need to perform coercion or casting when the `+` symbol is used with mixed arithmetic
- To use arithmetic symbols with our own objects ⇨ must overload the symbols
  - Polymorphism allows the same operations to be carried out differently
  - Overload the + operator with a reasonable meaning

A Starting Example

```
class CComplex {
    double real, imag;
public:
    CComplex() { real = 0; imag = 0; }
    CComplex(double r, double i) {
        real = r; imag = i; }
    CComplex cadd(CComplex & o2);
    void display() { cout << "(" << real
        << "," << imag << "i)" << endl }
};
CComplex CComplex::cadd(CComplex & o2) {
    CComplex c; c.real = real + o2.real;
    c.imag = imag + o2.imag; return c;
}
```

A Starting Example (cont.)

```
int main() {
    CComplex c1(3,4), c2(2,-7), c3;
    c3 = c1.cadd(c2);
    cout << "c1 = "; c1.display();
    cout << "c2 = "; c2.display();
    cout << "c1+c2 = "; c3.display();
    return 0;
}
```

```
c1 = (3,4i)
c2 = (2,-7i)
c1+c2 = (5,-3i)
```

- Using member function is cumbersome
  - good to have `c3 = c1 + c2`

Restrictions on Operator Overloading

- If an operator is normally defined to be unary only, then you cannot overload it to be binary
  - cannot change associativity or precedence
- Operators cannot be overloaded for built-in datatypes
  - The meaning of how an operator works on fundamental types cannot be changed by operator overloading.
    - You cannot, for example, change the meaning of how + adds two integers.
- You also cannot overload operators that you invent

Restrictions on Operator Overloading (cont.)

- Overloading an assignment operator and an addition operator to allow statements like
  - `object2 = object2 + object1;`
- does not imply that the += operator is also overloaded to allow statements such as
  - `object2 += object1;`
- Such behavior can be achieved only by explicitly overloading operator += for that class.

List of Overloading Operators

- Arithmetic
  - `+, -, *, /, %`
- Bitwise
  - `^, &, |, ~, >>, <<`
- Correlational
  - `<, <=, >, >=, !=, ==`
- Logic
  - `!, &&, ||`
- Assignment
  - `=, +=, -=, *=, /=, %=, <<=, >>=, &=, ^=,|=`
- Other
  - `++, --, [], (), ->, new, new [], delete, delete []`

List of Overloading Operators (cont.)

- Four operators cannot be overloaded

operator	usual use
. (dot operator)	member
.*	pointer to member
::	scope resolution
?:	conditional

Operator Functions as Class Members vs. Global Functions

- Operator functions can be member functions or global functions.

- Member Function
  - use the `this` pointer implicitly to obtain one of their class object arguments (the left operand for binary operators).

- Global Function
  - Arguments for both operands of a binary operator must be explicitly listed in a global function call.
  - Global functions are often made `friends` for performance reasons.

Operator Functions as Class Members

- When overloading `()`, `[]`, `->` or any of the `assignment operators`, the operator overloading function must be declared as a class member.

- For the other operators, the operator overloading functions can be class members or standalone functions.

Operator s as Class Members and Global Functions

- When an operator function is implemented as a member function, the leftmost (or only) operand must be an object (or a reference to an object) of the operator's class.

```
Complex a, b, c;
c = a.add(b);   c = a + b;   c =a.operator+(b);
```

- If the left operand must be an object of a different class or a fundamental type, this operator function must be implemented as a global function (as we'll do with `<<` and `>>`).
- A global operator function can be made a `friend` of a class if that function must access private or protected members of that class directly.

Member vs. Friend Functions

- Implement the overloading operation as a member function
  - use this to visit the data member
  - The left operand must be a object of same class, ex: c1+c2
- What if c3 = c1 + i ?

```
CComplex CComplex::operator+(int& i){
    return CComplex(real+i,imag); }
```

- What if c3 = i + c2 ? ⇨ use a friend function

```
CComplex operator+(int& i, CComplex& c){
    return CComplex(i+c.real,c.imag); }
```

Overloading Stream Insertion (<<) and Stream Extraction (>>) Operators

- You can input and output fundamental-type data using the stream extraction operator >> and the stream insertion operator `<<`.
- The C++ class libraries overload these operators to process each fundamental type, including pointers and C-style `char *` strings.
- You can also overload these operators to perform input and output for your own types.
  - `cin >> myObject;`
  - `cout << myObject;`
    Instead of need for:
    `myObject.output();`

Example

- The following program overloads >> and << operators to input and output `PhoneNumber` objects in format “(000) 000-0000”.

PhoneNumber.h

```
// Fig. 18.3: PhoneNumber.h
// PhoneNumber class definition
#ifndef PHONENUMBER_H
#define PHONENUMBER_H
#include <iostream>
#include <string>
using namespace std;
class PhoneNumber
{
    friend ostream &operator<<(ostream &, const
PhoneNumber &);
    friend istream &operator>>(istream &, PhoneNumber &);
private:
    string areaCode; // 3-digit area code
    string exchange; // 3-digit exchange
    string line;     // 4-digit line
}; // end class SalesPerson
#endif
```

PhoneNumber.cpp

```
// Fig. 18.4: PhoneNumber.cpp
#include <iomanip>
#include "PhoneNumber.h"
using namespace std;

// overloaded stream insertion operator; cannot be
// a member function if we would like to invoke it with
// cout << somePhoneNumber;
ostream &operator<<(ostream &output, const PhoneNumber
&number)
{
    output << "(" << number.areaCode << ")"
           << number.exchange << "-" << number.line;
    return output; //enables cout << a << b << c;
}
```

PhoneNumber.cpp (cont.)

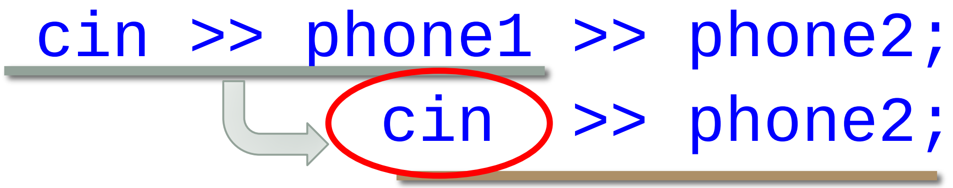
```
// overloaded stream extraction operator; cannot be
// a member function if we would like to invoke it with
// cin >> somePhoneNumber;
istream &operator>>(istream &input, PhoneNumber &number)
{
    input.ignore(); // skip (
    input >> setw(3) >> number.areaCode;
    input.ignore(2); // skip ) and space
    input >> setw(3) >> number.exchange;
    input.ignore();  // skip (-)
    input >> setw(4) >> number.line;

    return input; //enables cin >> a >> b >> c;
}
```

Fig19_05.cpp

```
// Fig. 18.5: fig18_05.cpp
// Demonstrating class PhoneNumber’s overloaded stream
// insertion and stream extraction operators.
#include <iostream>
#include "PhoneNumber.h"
using namespace std;
int main()
{
    PhoneNumber phone;  // create object phone
    cout << "Enter phone number in the format (123) 456-
7890: " << endl;
    // cin >> phone invokes operator>> by implicitly
    // issuing the global function call
    // operator>>(cin, phone)
    cin >> phone;
    cout << "The phone number entered was: ";
    cout << phone << endl;
    return 0;
}
```

Overloading >>

- Operands >>
  - `cin` object, of class type `istream`
  - our class type (`PhoneNumber`)
  - `cin >> phone;`
  - `operator>>(cin, phone)`
- Function `operator>>` returns `istream` reference input (i.e., `cin`).
  - Enables input operations on `PhoneNumber` objects to be cascaded with input operations on other `PhoneNumber` objects or on objects of other datatype.



```
cin >> phone1 >> phone2;
           cin >> phone2;
```

Overloading Unary Operators

- We overload unary operator ! To test whether an object of a String class we create is empty and return a bool result.
- A unary operator for a class can be overloaded
  - as a non-static member function with **no** arguments

```
class String {
public:
    bool operator!() const;
};
```

  - as global function with **one** argument that must be an object (or a reference to an object) of the class

```
bool operator!(const String&);
```

Overloading Binary Operators

- We overload `<` to compare two `String` objects.
- A binary operator for a class can be overloaded
  - as a non-static member function with **one** arguments
  - `y < z;    =>  y.operator<(z);`

```
class String {
public:
   bool operator<(const String &) const;
};
```

  - as global function with **two** arguments – one of which must be an object (or a reference to an object) of the class

```
bool operator<(const String&, const String&);
```

Case Study: `Array` Class

- Pointer-based arrays have many problems
  - A program can easily "walk off" either end of an array, because C++ does not check whether subscripts fall outside the range of an array.
  - Arrays of size n must number their elements 0, ..., n – 1; alternate subscript ranges are not allowed.
  - An entire array cannot be input or output at once.
  - Two arrays cannot be meaningfully compared with equality or relational operators.
  - When an array is passed to a general-purpose function designed to handle arrays of any size, the array's size must be passed as an additional argument.
  - One array cannot be assigned to another with the assignment operator.

Case Study: `Array` Class (cont.)

- In this example, we create a powerful `Array` class:
  - Performs range checking.
  - Allows one array object to be assigned to another with the assignment operator.
  - Objects know their own size.
  - Input or output entire arrays with the stream extraction and stream insertion operators, respectively.
  - Can compare Arrays with the equality operators == and !=.

Array.h

```
// Fig. 18.10: Array.h
// Array class definition with overloaded operators
#ifndef ARRAY_H
#define ARRAY_H
class Array
{
    friend ostream &operator<<(ostream &, const Array &);
    friend istream &operator>>(istream &, Array &);
public:
    Array( int = 10);  // default constructor
    Array (const Array &); // copy constructor
    ~Array();              // destructor
    int getSize() const;   // return size
    const Array &operator=(const Array &); // assignment
    bool operator==(const Array &); const  // equality
```

Array.h (cont.)

```
    bool operator!=( const Array &right) const
    {
        // invokes Array::operator==
        return !(*this == right);
    }
    // subscript operator for non-const objects
    // returns modifiable lvalue
    int &operator[]( int );
    // subscript operator for const objects returns rvalue
    int operator[]( int ) const;
private:
    int size;  // pointer-based array size
    // pointer to first element of pointer-based array
    int *ptr;
}; // end class Array
#endif
```

Array.cpp

```
// Fig. 18.11: Array.cpp
#include <iostream>
#include <iomanip>
#include <cstdlib>   // exit function prototype
#include "Array.h"
using namespace std;
Array::Array(int arraySize) { // constructor
    size = (arraySize > 0 ? arraySize : 10);
    ptr = new int[size];
    for (int i = 0; i < size; i++)
        ptr[i] = 0;
}
// copy constructor
Array::Array(const Array &arrayToCopy)
                              :size(arrayToCopy.size) {
    ptr = new int[size];
    for (int i = 0; i < size; i++)
        ptr[i] = arrayToCopy.ptr[i];
}
```

Array.cpp (cont.)

```
Array::~Array() { // destructor
    delete [] ptr;
}
// return number of elements of Array
int Array::getSize() const
{
    return size;
}
// determine if two Arrays are equal and return true
bool Array::operator==( const Array &right) const
{
    if (size != right.size)
        return false;
    for (int i = 0; i < size; i++)
        if ( ptr[i] != right.ptr[i] )
            return false;
    return true;
}
```

Array.cpp (cont.)

```
// overloaded assignment operator;
// const return avoids: ( a1 = a2 ) = a3
const Array &Array::operator=( const Array &right)
{
    if ( &right != this ) // avoid self-assignment
    {
        // for Arrays of different sizes, deallocate
        // original left-side array, then allocate new
        // left-side array
        if ( size != right.size)
        {
            delete [] ptr;     // release space
            size = right.size; // resize this object
            ptr = new int[size];
        }
        for (int i = 0; i < size; i++)
            ptr[i] = right.ptr[i];
        return *this; // enable x = y = z;
    }
```

Array.cpp (cont.)

```
// overloaded subscript operator for non-const Arrays;
// reference return creates a modifiable lvalue
int &Array::operator[]( int subscript)
{
    // check for subscript out-of-range error
    if ( subscript < 0 || subscript >= size)
    {
        cerr << "\nError: Subscript " << subscript
             << " out of range" << endl;
        exit(1);  // terminate program;
    }
    return ptr[subscript]; // reference return
}
```

Array.cpp (cont.)

```
// overloaded subscript operator for const Arrays;
// const reference return creates an rvalue
int Array::operator[]( int subscript) const
{
    // check for subscript out-of-range error
    if ( subscript < 0 || subscript >= size)
    {
        cerr << "\nError: Subscript " << subscript
             << " out of range" << endl;
        exit(1);  // terminate program;
    }
    return ptr[subscript]; // returns copy of this element
}
```

Array.cpp (cont.)

```
// overloaded input operator for class Arrays;
// inputs values for entire Array
istream &operator>>( istream &input, Array & a) {
    for ( int i = 0; i < a.size; i++)
        input >> a.ptr[i];
    return input; // enables cin >> x >> y >> z;
}
// overloaded output operator for class Arrays;
ostream &operator<<( ostream &output, const Array & a) {
    int i;
    for ( i = 0; i < a.size; i++) {
        output << setw(12) << a.ptr[i];
        if ((i+1)%4 == 0)  // 4 numbers per row for output
            output << endl;
    }
    if ( i % 4 != 0)  // end last line of output
            output << endl;
    return output; // enables cin >> x >> y >> z;
}
```

Fig19_08.cpp

```
// Fig. 18.9: fig18_09.cpp
// Array class test program.
#include <iostream>
#include "Array.h"
using namespace std;
int main()
{
    Array array1(7);  // 7-element Array
    Array array2;     // 10-element Array
    cout << "Size of Array array1 is "
         << array1.getSize()
         << "\n Array after initialization: \n" << array1;

    cout << "\nEnter 17 integers:" << endl;
    cin >> array1 >> array2;

    cout << "array1: \n" << array1
         << "array2: \n" << array2;
```

Fig19_08.cpp (cont.)

```
    // use overloaded inequality (!=) operator
    cout << "\nEvaluating: array1 != array2" << endl;
    if ( array1 != array2)
        cout << "array1 and array2 are not equal\n";

    Array array3(array1);  // invoke copy constructor

    // use overloaded assignment (=) operator
    cout << "\nAssigning array2 to array1:" << endl;
    array1 = array2;
    cout << "array1: \n" << array1
         << "array2: \n" << array2;
    // use overloaded equality (==) operator
    cout << "\nEvaluating: array1 == array2" << endl;
    if ( array1 == array2)
        cout << "array1 and array2 are equal\n";
```

Fig19_08.cpp (cont.)

```
    // use overloaded subscript operator to create rvalue
    // array1[5]  => array.operator[](5)
    cout << "\narray1[5] is " << array1[5];

    // use overloaded subscript operator to create lvalue
    cout << "\nAssigning 1000 to array1[5]" << endl;
    array1[5] = 1000;
    cout << "array1: \n" << array1;

    // attempt to use out-of-range subscript
    cout << "\nAttempt to assign 1000 to array1[15]" <<
endl;
    array1[15] = 1000; // ERROR: output of range

    return 0;
}
```

Overload Array Operator [ ]

- Can overload `[ ]` for your class
  - used with objects of your class
  - typically, `x[i]` ⇔ `*(x+i)`
  - a binary operator: the left operand is a reference object + the right one is an integer
- Format
  - operator must return a reference
  - operator `[ ]` must be a member function

```
⟨cname⟩& ⟨cname⟩::operator[](int i)
{ //functional body; }
```

Example of Overloading [ ]

- New class CData with a short integer array

```
class CData {
    int len; short *sary;
public:
    CData(unsigned long n = 0) {
        unsigned long temp = n; len = 1;
        while (temp > 10)
            { temp = temp/10; len++; }
        sary = new short[len];
        for (int i=0; i<len; ++i)
            { sary[i] = n%10; n /=10;}
    }
};
```

Example of Overloading [ ] (cont.)

```
class CData {
    ~CData() {
        if (sary) { delete [] sary;
            sary = NULL; }                }

    void display() {
        for (int i=len-1; i>=0; i--)
            { cout << *(sary+i); }
        cout << endl;                     }

    short& operator[](int i) {
        if (i>=len) { cerr << "Error"; }
        return *(sary+i);                 }
};
```

Example of Overloading [ ] (cont.)

```
//in main()
    CData x(9316);
    x.display();
    cout << "x[0] = " << x[0]
         << ", x[3] = " << x[3] << endl;
    x[0] = 2;
    x[3] = 7;
    x.display();
```

```
9316
x[0] = 6, x[3] = 9
7312
```

Converting between Types

- C++ provides explicit type conversion
  - `<datatype>(<data>)`, ex: `int(82.7)`
  - `(<datatype>)<data>`, ex: `(double)49`
- Conversion constructor casts the data of one type into an object of another class, ex

```
class CComplex {
    CComplex(double r) {
        real = r; imag = 0;              }
};
```

```
CComplex o1(4.2);
CComplex o2 = o1 + CComplex(2.5);
```

Type Casting for Class

- What is converting a `CComplex` into a `double`?
  - need a type conversion function
  - Format:

```
⟨cname⟩::operator⟨datatype⟩ ()
    { //functional body; }
```

- Example

```
class CComplex {
    operator double(){ return real; }
};
```

  - cannot assign the return datatype
  - cannot have any parameter

```
CComplex o1(4.2); double d2 = 12;
double d3 = d2 + o1;
```

Overloading ++ and - -

- ++/-- are unary operators
  - prefix operation: ++obj, --obj
  - postfix operation: obj++, obj--
- Declaration of member functions

```
⟨CNAME⟩ &⟨CNAME⟩::operator++(); //prefix
⟨CNAME⟩ ⟨CNAME⟩::operator++(int); //postfix
```

- Declaration of friend functions

```
//prefix friend function
friend ⟨CNAME⟩ & operator++(⟨CNAME⟩&);
//postfix friend function
friend ⟨CNAME⟩ operator++(⟨CNAME⟩&, int);
```

Example of Overloading ++

```
class CCount {
    unsigned int unCnt;
public:
    CCount(int n = 0) { unCnt = 0; }
    void display() { cout << unCnt; }
    //prefix increment with member function
    CCount& operator++();
    //postfix increment with global funciton
    friend CCount operator++(CCount&, int);
};
CCount& CCount::operator++() {
    unCnt++; return *this;                }
CCount operator++(CCount& x, int y) {
    CCount tmp = x; x.unCnt++; return tmp;  }
```

Example of Overloading ++ (cont.)

```
//in main()
    CCount d1(12), d2;
    d2=d1++; //call postfix increment
    d1.display();d2.display();cout << endl;
    d2=++d1; //call prefix increment
    d1.display();d2.display();cout << endl;
    ++++d1;
    d1.display();d2.display();cout << endl;
```

```
13 12
14 14
16 14
```

Summary

- C++ built-in operators can be overloaded
  - to work with objects of your class
- Operators are really just functions
- Operators can be overloaded as member functions where
  - the first operand is the calling object
- Overloading operators can be classified into
  - overloading member functions
  - overloading friend functions

References

- Paul Deitel and Harvey Deitel, “C How to Program” Sixth Edition
  - Chapter 18

- Paul Deitel and Harvey Deitel, “C++ How to Program (late objects version)” Seventh Edition
  - Chapter 11: Operator Overloading

- W. Savitch, “Absolute C++,” Fourth Edition
  - Chapter 8