Operator overloading: extra examples

CS319: Scientific Computing (with C++)

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Some extra examples, to supplement what was covered in class

1. Eg 1: Points in the (x, y)-plane
   - Overloading `operator+`
   - Overloading `operator+` again
2. Unary operators
3. The Conditional Operator `?:`
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5. Overloading ++
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Eg 1: Points in the (x, y)-plane

We will create an object to represent points in the (x, y)-plane:

- with two private members: floats x and y,
- constructor to initialise x and y; it will have default values.
- a public function `Get`, used to find the values of x and y,
- a public function `Set` that can be used to set the values of x and y,
- a public overloaded operator $+$ to add two points.

Eg 1: Points in the (x, y)-plane

Our first version of class declaration is shown opposite. The constructor function is defined in the declaration of the class, and has default values.

01Points.cpp

```
1  class Point {
   private:
3     float x,y;
   public:
5    Point(float i=0, float j=0) { x=i; y=j;};
     void Set(float i, float j) {x=i; y=j;};
7    void Get(float &i, float &j) {i=x; j=y;};
   };
```

If an object of type `Point` is declared as `Point a;` then `a.Point()` is called as if it was `Point(0.0, 0.0)`.

If `a` is declared as: `Point a(-2,3);` then these two floats are passed to the constructor.

The public `Set()` allows us to set the values of `a.x` and `a.y`

In the definition of `Get()`, the integer variables are passed **by reference** and not by value – therefore the value of `i` and `j` are modified by the function.

Now we add the code for the + operator.

First, to the class definition we add the declaration of the operator:

```
Point operator+(Point b);
```

So now the class definition is

```
class Point {
private:
   float x,y;
public:
  Point(float i=0, float j=0) { x=i; y=j;};
  void Set(float i, float j) {x=i; y=j;};
  void Get(float &i, float &j) {i=x; j=y;};
  Point operator+(Point b);
};
```

Notice that it seems to suggest that + takes just one argument...

And then we give the definition:

```
10 Point Point::operator+(Point b)
   {
12   Point temp;
     temp.x = x + b.x;
14   temp.y = y + b.y;
     return temp;
16 }
```

The first thing to notice is that, although + is a binary operator, our function takes only one argument.

This is because, when we call the operator, e.g., `c = a + b` then `a` is passed **implicitly** to the function and `b` is passed **explicitly**. Therefore `a.x` is known to the function simply as `x`.

The temporary object `temp` is used inside the object to store the result. It is this object that is return.
Neither *a* or *b* are modified..

We'll now try overloading the `+` operator again, for the purpose of introducing the `*this` pointer.

Suppose that we have a point $b = (3.1, 2.2)$. If we write $a = b + 0.5$ and mean that we want to set $a = (3.6, 2.7)$.

```
class Point
{
private:
  float x,y;
public:
  Point(float i=0, float j=0) { x=i; y=j;};
  void Set(float i, float j) {x=i; y=j;};
  void Get(float &i, float &j) {i=x; j=y;};
  Point operator+(Point b);
  Point operator+(float p);
};
```

And the rest of the code would be

```
Point Point::operator+(float p)
{
  Point temp;
  temp.x = this->x + p;
  temp.y = this->y + p;
  return temp;
}
```

or

```
Point Point::operator+(float p)
{
  Point temp(*this);
  temp.x += p;
  temp.y += p;
  return temp;
}
```

Unary operators

So far we have discussed just the **binary** operator +. That is, it is an example of an operator that takes two arguments.

But many operators in C/C++ are *Unary*: they take only one argument.

The most common examples of unary operators are ++ and --, but we'll first over load the - (minus) operator. Note that this can be used in two ways:

- $c = a - b$ (binary)
- $c = -a$ (unary).

In the second case here, "minus" is an example of a *prefix* operator. These are the easiest.

Unary operators

```
//////////////////////
// Overloading BINARY minus
Point Point::operator-(Point b)
{
  Point temp;
  temp.x = x - b.x;
  temp.y = y - b.y;
  return temp;
}

// Overloading UNARY minus
Point Point::operator-(void)
{
  Point temp;
  temp.x = -x;
  temp.y = -y;
  return temp;
}
```

The Conditional Operator ?:

C and C++ have a selection of

- unary operators, e.g., `+`, `-`, `!`, `++` and `--`.
- And binary operators, e.g., `+`, `-`, `*`, `/`, `%`, `=`, `<`, `>`, `+=`, etc.

But it has only one **ternary** operator (one that takes **3** arguments), and that is the conditional operator `?:`.

Syntax: *Cond ? Op of Cond True : Op if Cond False*

The Conditional Operator ?:

See `02Ternary.cpp` for more details

```
 8   int Score;
     std::string Grade, Outcome;

     std::cout << "Enter your score: ";
12   std::cin >> Score;

14   (Score >= 40) ? Grade="Pass" : Grade="Fail";
     std::cout << "You have " << Grade << "ed." << std::endl;

     // Alternative
18   std::cout << "Enter another score: ";
     std::cin >> Score;
20   Outcome = (Score >= 40) ? "will not" : "will";
     std::cout << "You " << Outcome << " have to come back in Augest!"
22             << std::endl;
```

Prefix and Postfix ++

We all know that in C/C++ one can use the `++` and `--` operators in prefix and post fix forms, e.g.,

- `++a` (prefix)
- `a++` (postfix)

But what is the difference?

In C/C++, all expressions – including assignments such as `a++` – must evaluate as something. So

- `++a` evaluates as `a+1`, the value *after* incrementation,
- `a++` evaluates as `a`, the value *before* incrementation.

```
int a, b;
a=1;   b=(a++);
std::cout << "a=" << a << ", b=" << b << endl;

a=1;    b=(++a);
std::cout << "a=" << a << ", b=" << b << endl;
```

output

```
a=2, b=1

a=2, b=2
```

Prefix and Postfix ++

And there is a further distinction between the preincrement (`++a`) and postincrement (`a++`) operators: the preincrement operator can be used as the left operand in an assignment.

```
// Use prefix and postfix ++
#include <iostream>
int main(void)
{
   int a, b;

   a=10; b=20;
// The following would be illegal
// (a++)=b;
   (++a)=b; // ¡- But this is OK!
   std::cout << "a=" << a << ", b=" << b << std::endl;
   return(0);
}
```

Overloading ++

Overloading both the prefix and postfix versions of `++` involve a number of technicalities, specifically

(1) There has to be a way of distinguishing between the two forms. This is achieved by giving the postincrement operator a dummy `int` as an argument. That way the two versions have different **signatures**.

(2) We may wish to maintain the usual way the operators work (i.e., whether they evaluate as the original or incremented version, and if they can be used as **left values** in assignment operations).
This is achieved as follows:
   (a) The postincrement operator makes a copy of the object before the increment, and then returns the (original, unincremented) copy.
   (b) Typically, preincrement operator will return a reference (address), and the postincrement operator will return a value. This allows the preincrement op to be used as the left value in an assignment.

The example we'll use to study this is a class to implement the current date.

03Date++.cpp

```
// CS319 Operator Overloading: Extras
// Date: a class representing a calendar date
// Example of overloading the ++ operator
#include <iostream>

int StandardDaysMonth[] =
   {0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};

class Date {
public:
   Date (int d=1, int m=1, int y=1901);
   void SetDate(int dd, int mm, int yy);
   int GetDay(void) {return day;};
   int GetMonth(void) {return month;};
   int GetYear(void) {return year;};
   bool IsLeapYear(void);

   Date &operator++(void); // prefix version
   Date operator++(int Dummy); // postfix

private:
   int day, month, year;
   int *DaysMonth;
   void Increment(void);
};
```

```
28 // Constructor
   Date::Date(int d, int m, int y)
30 {
      DaysMonth = new int [13];
32    for (int i=0; i<=12; i++)
         DaysMonth[i] = StandardDaysMonth[i];
34    SetDate(d,m,y);
   }


38 bool Date::IsLeapYear(void)
   {
40    if ( (year%400 == 0) ||
           ( (year%4 == 0) && (year%100 != 0)))
42       return true;
      else
44       return false;
   }
```

```
void Date::SetDate(int d, int m, int y)
{
   year=y;
   if (IsLeapYear())
      DaysMonth[2]=29;

   month = ( (m>=1) && (m<=12) ) ? m : 1;

   day = ( (d>=1) && (d<=DaysMonth[month]) ) ? d : 1;
}
```

```
// Will call this in both prefix and postfix versions.
void Date::Increment(void)
{
   if (day != DaysMonth[month])
      day++;
   else if ( month != 12 )
   {
      month++; day=1;
   }
   else
      SetDate(1,1,year+1); // Need to set the leap year
}
```

```
Date &Date::operator++(void) // Prefix version
{
   Increment();
   return(*this);
}

Date Date::operator++(int Dummy)  // Postfix version
{
   Date temp=*this;
   Increment();
   return(temp);
}
```

```
84  int main(void)
    {
86    Date today(13,03,2024);
      Date tomorrow, NextMonday;

      cout << "Today is " << today.GetDay() << "/" <<
90      today.GetMonth() << "/" << today.GetYear() << endl;

92    tomorrow=(++today);
      cout << "Tomorrow is " << tomorrow.GetDay() << "/" <<
94      tomorrow.GetMonth() << "/" << tomorrow.GetYear() << endl;


      for (int i=1; i<5; i++)
98       ++today;

100   NextMonday = today;
      cout << "Next Monday is " << NextMonday.GetDay() << "/" <<
102      NextMonday.GetMonth() << "/" << NextMonday.GetYear() << endl;

104   cout << endl;

106   return(0);
    }
```

`friend` functions

In all the examples that we have seen so far, the only functions that may access private data belonging to an object has been a member function/method of that object.

However, it is possible to designate non-member as being `friends` of a class.

For non-operator functions, there is nothing that complicated about `friend`s. However, care must be taken when overloading operators as `friend`s.

In particular:

- All arguments are passed explicitly to `friend` functions/operators.
- Certain operators, particularly the **Put to** `<<` and **Get from** `>>` operators can only be overloaded as friends.

friend functions

04DatePutTo.cpp

```
1  class Date // New version to overload <<
   {
3    friend std::ostream &operator<<(std::ostream &, const Date &);

5    public:
       Date (int d=1, int m=1, int y=1901);
7  .
   .
9  .
   std::ostream &operator<<(std::ostream &output, const Date &d)
11 {
     std::string MonthName[13]={"", "Jan", "Feb", "Mar", "Apr",
13     "May", "Jun", "Jul", "Aug", "Sep",
       "Oct", "Nov", "Dec"};
15   output << d.day << "/" << MonthName[d.month] << "/"
        << d.year;
17   return(output);
   }
```

Another example: complex numbers

In order to increase the number of examples of classes that you have studied, and to give a framework to consider come technical issues, we introduce a `class` for **Complex Numbers**.

A **complex number** is

$$z = a + bi \text{ where } a \text{ and } b \text{ are real numbers and } i = \sqrt{-1}.$$

So our class will have two private data elements for the **real** and **imaginary** parts, as we as methods to get and set their values.

Another example: complex numbers

05Complex.cpp

```
class Complex
{
private:
  float real, imag;
public:
  Complex (float r=0.0, float i=0.0) {Set(r,i);};
  float GetReal(void) {return(real);};
  float GetImag(void) {return(imag);};
  void Set(float r, float i=0.0);
};

void Complex::Set(float r, float i)
{
  real=r; imag=i;
}
```

Constants

Constant Variables: We are familiar with the idea of a `const` "variable". This is one whose value can not be changed after initialisation.

Constant Functions: In `C++` one may also force a class method to be constant. This is done by placing the keyword `const` at the end of the line containing the function prototype and header. The effect is that the function cannot modify the object.

Furthermore, if you wish to call a method belonging to a constant object, then the method must be constant.

In our example, we might define `const Complex I(0,1)` to represent $i = \sqrt{-1}$. But a call to `I.GetReal()` or `I.GetImag()` as presented above would give an error, such as

```
error: passing ‘const Complex’ as ‘this’ argument of
‘float Complex::GetImag()’ discards qualifiers
```

Constants

```
class Complex
{
    private:
        float real, imag;
    public:
        Complex (float r=0.0, float i=0.0) {Set(r,i);};
        float GetReal(void) const;
        float GetImag(void) const;
        void Set(float r, float i=0.0);
};

float Complex::GetReal(void) const
{
    return(real);
}
float Complex::GetImag(void) const
{
    return(imag);
}
```

`friends` again

Let's return to the idea of a `friend` function. This is a function that does not belong to the class, but still has access to private elements of a class.

There are two reasons you might want a function to be a `friend` of a class

- **Efficiency:** If the called function is not a `friend`, it will have to use some method to access private members. This can be slower than being able to access it directly.
- **Overloading:** When overloading an member operator for a class, the left argument must be an object of that class. So, for example,

```
Complex x(2.0, 3.0), z;
float f=3.0;
z = x*x; // * operator can be a member
z = x*f; // * operator can be a member
z = f*x; // * operator can't be a member
```

`friends` again

The left argument of an overloaded operator must be an object of the class. Therefore, we can only overload the **stream insertion** operator `<<` and **stream extraction** operator `>>` as `friend`s.

To see how this is done, have a look at `06ComplexMult.cpp`

This example also shows the three ways of overloading the `*` operator.

Note that,

- for a member operator, the left argument is implicit, and only the right argument is listed explicitly,
- for a non-member function, both the left and right arguments must be listed.