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C/C++ Program Design

CS205

Week 10

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Operators for `cv::Mat`



Function overloading

```
Mat add(Mat A, Mat B);  
Mat add(Mat A, float b);  
Mat add(float a, Mat B);
```

```
Mat mul(Mat A, Mat B);  
Mat mul(Mat A, float b);  
Mat mul(float a, Mat B);
```

...

More convenient to code as follows

```
Mat A, B;  
float a, b;  
//...  
Mat C = A + B;  
Mat D = A * B;  
Mat E = a * A;
```



operators for cv::Mat

```
yushiqi@Mac exampleMat % ./matexample
Matrix C =
[9, 12;
 18, 24]
```

```
#include <iostream>
#include <opencv2/opencv.hpp>

using namespace std;

int main()
{
    float a[6]={1.0f, 1.0f, 1.0f, 2.0f, 2.0f, 2.0f};
    float b[6]={1.0f, 2.0f, 3.0f, 4.0f, 5.0f, 6.0f};
    cv::Mat A(2, 3, CV_32FC1, a);
    cv::Mat B(3, 2, CV_32FC1, b);

    cv::Mat C = A * B;

    cout << "Matrix C = " << endl
         << C << endl;
    return 0;
}
```

The slides are based on the book <Stephen Prata, C++ Primer Plus, 6th Edition, Addison-Wesley Professional, 2011>

Operator Overloading



Overloading

- Function overloading
 - Let you use **multiple functions** sharing **the same name**
 - Relationship to others:
 - ✓ **Default** arguments
 - ✓ Function **templates**
- * operator (An operator overloading **example**)
 - Applied to **an address**, yield the value stored at that address
 - Applied **two numbers**, yield the product of the values



Operator Function

- Operator function

- Keyword: **operator** for C++
- To overload an operator, you use a **special function**
- Function header has the form:

`operator{op}(argument-list)`

- ✓ `operator+()` overloads the `+` operator
- ✓ `operator*()` overloads the `*` operator
- ✓ `operator[]()` overloads the `[]` operator
- The compiler, recognizing the **operands** as belonging to the class, replaces the **operator** with the corresponding **operator function**



Example: Time on Our Hands

- Developing an operator overloading

- The compiler uses the **operand types** to figure out what to do

```
int a, b, c;
Time A, B, C;
c = a + b;      // use int addition
C = A + B;     // use addition as defined for Time objects
```

- See program example 1

- The name of the **operator+()** function allows it to be invoked by using either **function notation** or **operator** notation

- Add **more than two** objects

```
t4 = t1 + t2 + t3;           // valid?
```

- **Left-to-right** operator

```
t4 = t1.operator+(t2 + t3);  // valid?
```

```
t4 = t1.operator+(t2.operator+(t3)); // valid? YES
```



Overloading Restrictions

- Must **have at least one operand** that is a **user-defined type**
- **Can't** violate the **syntax rules** for the **original** operator
- **Can't** alter operator **precedence**
- **Can't** create **new** operator **symbols**
- Use only **member functions** to overload these operators

Operator	Description
=	Assignment operator
()	Function call operator
[]	Subscripting operator
->	Class member access by pointer operator



Overloading Restrictions

- **Cannot** overload the following operators

Operator	Description
<code>sizeof</code>	The <code>sizeof</code> operator
<code>.</code>	The membership operator
<code>.*</code>	The pointer-to-member operator
<code>::</code>	The scope-resolution operator
<code>?:</code>	The conditional operator
<code>typeid</code>	An RTTI operator
<code>const_cast</code>	A type cast operator
<code>dynamic_cast</code>	A type cast operator
<code>reinterpret_cast</code>	A type cast operator
<code>static_cast</code>	A type cast operator



Operators That Can Be Overloaded

- Operators that **can** be overloaded

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

- See program example 2
 - More overloaded operators
 - ✓ **Subtract** one time from another
 - ✓ **Multiply** a time by a factor

The slides are based on the book <Stephen Prata, C++ Primer Plus, 6th Edition, Addison-Wesley Professional, 2011>

Friend functions



Introducing Friends

- Access control
 - Can access the **public portions directly**
 - Can access the **private members** of an object only by using the **public member functions**
 - Problems:
 - ✓ Public class methods serve as **the only access**
 - ✓ This restriction is **too rigid to fit particular problems**
- C++ provides another form of access: the **friend**
 - Friend **functions**
 - Friend **classes** - will be introduced later
 - Friend **member functions** - will be introduced later



Motivation for Friend Functions

- Problem: overloading a binary operator
 - **Left operand** is the invoking object
 - ✓ `Time Time::operator*(double mult) const`
 - ✓ `A = B * 2.75; A = B.operator*(2.75);`
 - ✓ `A = 2.75 * B; // cannot correspond to a member function`
- Solution: using a **nonmember** function
 - A nonmember function is **NOT** invoked by an **object**
 - Any values it uses, including objects, are **explicit arguments**
- Problem: ordinary nonmember functions **can't directly access** private data in a class



Creating Friends

- Making a function **a friend to a class**
 - Allow the function the **same access privileges** that a member function of the class has
- First step: place a **prototype** in the **class declaration** and prefix the declaration with the keyword: **friend**

```
friend Time operator*(double m, const Time & t); // goes in class declaration
```

- This prototype has three implications
 - ✓ **Not a member function**
 - ✓ **Isn't invoked** by using the membership operator
 - ✓ Has the **same access rights** as a member function



Creating Friends

- The second step is to write the function definition
 - Not a member function you **don't** use the **:: qualifier**
 - **Don't** use the **friend** keyword in the definition

```
Time operator*(double m, const Time & t) // friend not used in definition
{
    Time result;
    long totalminutes = t.hours * mult * 60 + t.minutes * mult;
    result.hours = totalminutes / 60;

    result.minutes = totalminutes % 60;
    return result;
}
```

- A friend function to a class is a **nonmember** function that has the **same** access rights as a **member** function
- See program example 2 (friend function)



More About Friends

- Summary

- Only a **class declaration** can decide which functions are friends, so the class declaration still controls which functions access private data
- Class methods and friends are simply two different mechanisms for **expressing a class interface**
- Overload an operator for a class and use the operator with a **nonclass term as the first operand**

```
Time operator*(double m, const Time & t)
{
    return t * m;    // use t.operator*(m)
}
```



A Common Kind of Friend: Overloading the << Operator

- A question?
 - Suppose trip is a **Time object**
 - ✓ `cout << trip; // make cout recognize Time class?`
 - Suppose fun is a **function name** - a question from one student
 - ✓ `cout << "(fun)= " << (void*)fun<< endl; // how about no (void*)`
- Heavily overloaded
 - << : **bit manipulation operators** - shifts bits left in a value
 - << : **output tool** - recognize all the basic C++ types.



The First Version of Overloading <<

- Use a Time **member function** to overload <<, the Time object would come first

- Be confusing

- The problem is the same to the overloaded *** operator**



➔ `trip << cout; // if operator<<() were a Time member function`

- Use a **friend function** to overload the operator:

```
[void]operator<<(ostream & os, const Time & t)
{
    os << t.hours << " hours, " << t.minutes << " minutes";
}
```

- **Enable** to have the original syntax of cout

```
cout << trip;
```



The Second Version of Overloading <<

- Consider the example:
 - Read the output statement from **left to right**
 - Return **a reference** to the invoking object—cout

```
int x = 5;
int y = 8;
cout << x << y;           (cout << x) << y;
                          ↑
                          cout
```

- **Problem:** `cout << "Trip time: " << trip << " (Tuesday)\n"; // can't do`

- Return **a reference** to an **ostream** object

```
{ ostream } & operator<<(ostream & os, const Time & t)
{
    os << t.hours << " hours, " << t.minutes << " minutes";
    [return os;]
}
```

- See program example 3



Overloaded Operators: Member Versus Nonmember Functions

- Have a choice between using **member** functions or **nonmember** functions to implement operator overloading
 - One: has the **prototype** in the Time **class declaration**
 - ✓ **One operand** is passed implicitly via the this pointer

```
Time operator+(const Time & t) const; // member version
```

- Two: use the prototype with keyword: **friend**

```
// nonmember version
```

```
friend Time operator+(const Time & t1, const Time & t2);
```

- Compiler can convert the statement

```
T1 = T2 + T3;      T1 = T2.operator+(T3);      // member function  
                  T1 = operator+(T2, T3);    // nonmember function
```

- Must choose **one form**

Automatic Conversions and Type Casts for Classes



Conversions for Built-in Types

- Generate **numeric** type conversions

```
long count = 8;      // int value 8 converted to type long
double time = 11;   // int value 11 converted to type double
int side = 3.33;    // double value 3.33 converted to type int 3
```

- **Recognize** that the diverse numeric types all represent the same basic thing—a **number**
 - Incorporate **built-in rules** for making the conversions
- **Does not** automatically convert types that are **not compatible**

```
int * p = 10; // type clash
```

```
int * p = [(int *)]10; // ok, p and (int *) 10 both pointers
```



Define a class related to **a** basic type or to **another** class

- See header file in **program example 4**

➤ Have **three** constructors

```
Stonewt blossom(132.5); // weight = 132.5 pounds
```

➤ Write code like the following

```
Stonewt buttercup(10, 2); // weight = 10 stone, 2 pounds
```

```
Stonewt bubbles; // weight = default value
```

```
Stonewt myCat; // create a Stonewt object
```

```
myCat = 19.6; // use Stonewt(double) to convert 19.6 to Stonewt
```

✓ Implicit conversion: happen automatically, **no** need **explicit** type cast

✓ Provided a **default value** for the second parameter

```
Stonewt(int stn, double lbs); // not a conversion function
```

```
Stonewt(int stn, double lbs = 0); // int-to-Stonewt conversion
```

✓ Explicit conversions: **turn off** the automatic aspect (keyword: **explicit**)

➡ `explicit Stonewt(double lbs); // no implicit conversions allowed`

```
Stonewt myCat; // create a Stonewt object
```

➡ `myCat = 19.6; // not valid if Stonewt(double) is declared as explicit`

```
mycat = Stonewt(19.6); // ok, an explicit conversion
```

```
mycat = (Stonewt) 19.6; // ok, old form for explicit typecast
```



When does the compiler use the Stonewt(double) function?

- Argument-matching process provided by function prototyping
 - If the **explicit** is used in the declaration, Stonewt(double) is used **only** for an **explicit type cast**
 - Otherwise, it is used for the following implicit conversions, when
 - ✓ **initialize** a Stonewt object to a **type double value**
 - ✓ **assign** a **type double value** to a Stonewt object
 - ✓ **pass** a **type double value** to a function that expects a Stonewt argument
 - ✓ a function that's **declared to return** a Stonewt value **tries to return** a double value
 - ✓ any of the preceding situations use a **built-in type** that can unambiguously be **converted** to **type double**
- Only a constructor that can be used with just one argument works as a conversion function



Conversion Functions

- Question: Can we do the **reverse**?

```
Stonewt wolfe(285.7);
```



```
double host = wolfe; // ?? possible ??
```

- **Yes, conversion function**

- User-defined type casts

```
Stonewt wolfe(285.7);
```

```
double host = double (wolfe); // syntax #1
```

```
double thinker = (double) wolfe; // syntax #2
```

- Use a conversion function in this form

```
operator typeName();
```

- ✓ Must **be** a **class method**
- ✓ Must **not** specify a **return type**
- ✓ Must have **no arguments**

```
Stonewt::operator double()const  
{  
    return pounds;  
}
```



No return type but has return value



Applying Type Conversions Automatically

- Problem: when **omit** the explicit type cast

```
cout << "Poppins: " << int(poppins) << " pounds.\n";  
Stonewt poppins(9,2.8); cout << "Poppins: " << poppins << " pounds.\n";  
  
long gone = poppins; // ambiguous
```

- The compiler complains about using an **ambiguous conversion**
- The class has defined **two** (double and int) conversion functions
- Use an **explicit type cast**, when the class defines **two or more** conversions

```
long gone = (double) poppins; // use double conversion  
long gone = int (poppins); // use int conversion
```



Solutions and Summary

- Solutions

- Declare a conversion operator as **explicit**

```
class Stonewt
{
...
// conversion functions
    explicit operator int() const;
    explicit operator double() const;
};
```

- Replace a conversion function with a **nonconversion** function

```
Stonewt::operator int() { return int (pounds + 0.5); }
```



```
int Stonewt::Stone_to_Int() { return int (pounds + 0.5); }
```

- Summary

- A **class constructor** that has but a **single argument** serves as an instruction for converting a value of the argument type to the class type
- **Conversion function** serves as an instruction for converting a class object to some other types