

## Chapter 11: Friends, Overloading, and const

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### friend functions

- `friend` functions are NOT member methods but have access to `private` members of that class
- `friend` functions must be named inside the class definition
- `friend` functions are always public regardless of where they are placed in the class definition
- We wary of using `friend` functions; they defeat the purpose of encapsulation, but can be necessary in some circumstances

### Number example

- Let's look at a `Number` class that uses a friend function to add two `Numbers` together
- Notice we didn't have to define the `add` function in the scope of `Number` (i.e. we didn't have to write `Number Number::add(Number left, Number right)`)
  - This is a bit unusual, but it's because `friend` functions aren't actually a member of the class

### Example NumberDriver.cpp

```
1 // NumberDriver.cpp : Defines the entry point for the console
  application.
2 //
3
4 #include <iostream>
5 #include <cstdlib>
6
7 #include "Number.h"
8
9 using namespace std;
10
11 Number add( Number left, Number right );
12
13 int main(int argc, char* argv[])
14 {
15     cout << "----120----" << endl;
16     Number n = Number( 120 );
```

```
17     n.printRomanNumeral();
18
19     cout << "----99----" << endl;
20     n.setValue( 99 );
21     n.printRomanNumeral();
22
23     Number four = Number( 4 );
24     Number five = Number( 5 );
25     Number nine = add( four, five );
26
27     cout << "----9----" << endl;
28     nine.printRomanNumeral();
29
30     return( 0 );
31 }
```

### Example Number.h

```
1  #ifndef NUMBER_H
2  #define NUMBER_H
3
4  #include <iostream>
5  #include <cstdlib>
6
7  using namespace std;
8
9
10 class Number {
11 public:
12     Number();
13     Number( int initValue );
14
15     void setValue( int v );
16     int  getValue();
17     void printRomanNumeral();
18
19     friend Number add( Number left, Number right );
20 private:
21     int value;
22 };
23
24 #endif
```

**Example Number.cpp**

```
1  #include <iostream>
2  #include <cstdlib>
3
4  #include "Number.h"
5
6  using namespace std;
7
8  // note the friend function is not a member function
9  Number add( Number left, Number right ) {
10     Number temp = Number( left.value + right.value );
11     return( temp );
12 }
13
14 Number::Number() {
15     value = 0;
16 }
17
18 Number::Number( int initValue ) {
19     value = initValue;
20 }
21
22 void Number::setValue( int v ) {
23     value = v;
24 }
25
26 int Number::getValue() {
27     return( value );
28 }
29
30 void Number::printRomanNumeral() {
31     // uses cout
32     int remainder = value;
33     int thousands = remainder / 1000;
34     remainder -= thousands * 1000;
35     int fivehundreds = remainder / 500;
36     remainder -= fivehundreds * 500;
37     int hundreds = remainder / 100;
38     remainder -= hundreds * 100;
```

```
39     int fiftys = remainder / 50;
40     remainder -= fiftys * 50;
41     int tens = remainder / 10;
42     remainder -= tens * 10;
43     int fives = remainder / 5;
44     remainder -= fives * 5;
45     int ones = remainder;
46
47     int i;
48
49     for (i = 1; i <= thousands; ++i)
50         cout << "M";
51     if (fivehundreds == 1 && hundreds == 4) {
52         cout << "CM";
53         fivehundreds = 0;
54         hundreds = 0;
55     }
56     for (i = 1; i <= fivehundreds; ++i)
57         cout << "D";
58     if (hundreds == 4) {
59         cout << "CD";
60         hundreds = 0;
61     }
62     for (i = 1; i <= hundreds; ++i)
63         cout << "C";
64     if (fiftys == 1 && tens == 4) {
65         cout << "XC";
66         fiftys = 0;
67         tens = 0;
68     }
69     for (i = 1; i <= fiftys; ++i)
70         cout << "L";
71     if (tens == 4) {
72         cout << "XL";
73         tens = 0;
74     }
75     for (i = 1; i <= tens; ++i)
76         cout << "X";
77     if (fives == 1 && ones == 4) {
78         cout << "IX";
79         ones = 0;
80         fives = 0;
81     }
```

```
82     for (i = 1; i <= fives; ++i)
83         cout << "V";
84     if (ones == 4) {
85         cout << "IV";
86         ones = 0;
87     }
88     for (i = 1; i <= ones; ++i)
89         cout << "I";
90     cout << endl;
91 }
```

### const revisited

- Remember our qualifier **const**. It makes the type unmodifiable, meaning the value is not allowed to be changed.
  - If we wrote **const int a = 5**; it means the integer **a** is initialized to 5 and cannot be changed to a value other than 5
- For a quick example:

```
1  const int DAYS_IN_WEEK = 7;
2
3  for (int i = 0; i < DAYS_IN_WEEK; i++) {
4      read_textbook_chapter();
5      study();
6  }
```

- **const** can also be applied to function parameters (as was briefly mentioned with the notes on pass-by-reference)
  - **const** is unnecessary with call-by-value parameters
  - **const** can be applied to call-by-reference parameters
    - \* We should prefer to use call-by-reference when we are passing objects (from either structs or classes)
    - \* If no changes are made to the object, we can pass by constant reference (e.g. **const MyClass& my\_object**)
- **const** can also be applied to member functions. This means the function is not allowed to modify the object; i.e. the function is not allowed to modify an member variables.

### const Number example

- Notice our `printRomanNumeral()` method is a **const** method (not allowed to modify member variables of the object)
- Notice we passed `left` and `right` by constant reference to the `add()` *friend* function

### Example ConstDriver.cpp

```
1 // ConstDriver.cpp : Defines the entry point for the console
  application.
2 //
3
4 #include <iostream>
5 #include <cstdlib>
6
7 #include "Number.h"
8
9 using namespace std;
10
11 int main(int argc, char* argv[])
12 {
13     Number four = Number( 4 );
14     Number five = Number( 5 );
15     Number nine = add( four, five );
16
17     cout << "----9----" << endl;
18     nine.printRomanNumeral();
19
20     return( 0 );
21 }
```

### Example Number.h

```
1 #ifndef NUMBER_H
2 #define NUMBER_H
3
4 #include <iostream>
5 #include <cstdlib>
6
7 using namespace std;
8
```

```
9
10 class Number {
11 public:
12     Number();
13     Number( int initValue );
14
15     void setValue( int v );
16     int  getValue() const;
17     void printRomanNumeral() const;
18
19     friend Number add( const Number& left, const Number& right );
20 private:
21     int value;
22 };
23
24 #endif
```

### Example Number.cpp

```
1 #include <iostream>
2 #include <cstdlib>
3
4 #include "Number.h"
5
6 using namespace std;
7
8 // note the friend function is not a member function
9 // note the use of the const modifier
10 Number add( const Number& left, const Number& right ) {
11     Number temp = Number( left.value + right.value );
12     return( temp );
13 }
14
15 Number::Number() {
16     value = 0;
17 }
18
19 Number::Number( int initValue ) {
20     value = initValue;
21 }
22
23 void Number::setValue( int v ) {
```

```
24     value = v;
25 }
26
27 // note the use of the const modifier
28 int Number::getValue() const {
29     return( value );
30 }
31
32 // note the use of the const modifier
33 void Number::printRomanNumeral() const {
34     // uses cout
35     int remainder = value;
36     int thousands = remainder / 1000;
37     remainder -= thousands * 1000;
38     int fivehundreds = remainder / 500;
39     remainder -= fivehundreds * 500;
40     int hundreds = remainder / 100;
41     remainder -= hundreds * 100;
42     int fiftys = remainder / 50;
43     remainder -= fiftys * 50;
44     int tens = remainder / 10;
45     remainder -= tens * 10;
46     int fives = remainder / 5;
47     remainder -= fives * 5;
48     int ones = remainder;
49
50     int i;
51
52     for (i = 1; i <= thousands; ++i)
53         cout << "M";
54     if (fivehundreds == 1 && hundreds == 4) {
55         cout << "CM";
56         fivehundreds = 0;
57         hundreds = 0;
58     }
59     for (i = 1; i <= fivehundreds; ++i)
60         cout << "D";
61     if (hundreds == 4) {
62         cout << "CD";
63         hundreds = 0;
64     }
65     for (i = 1; i <= hundreds; ++i)
66         cout << "C";
```



```
67     if (fiftys == 1 && tens == 4) {
68         cout << "XC";
69         fiftys = 0;
70         tens = 0;
71     }
72     for (i = 1; i <= fiftys; ++i)
73         cout << "L";
74     if (tens == 4) {
75         cout << "XL";
76         tens = 0;
77     }
78     for (i = 1; i <= tens; ++i)
79         cout << "X";
80     if (fives == 1 && ones == 4) {
81         cout << "IX";
82         ones = 0;
83         fives = 0;
84     }
85     for (i = 1; i <= fives; ++i)
86         cout << "V";
87     if (ones == 4) {
88         cout << "IV";
89         ones = 0;
90     }
91     for (i = 1; i <= ones; ++i)
92         cout << "I";
93     cout << endl;
94 }
```

## Overloading operators

```
1  Number four = Number(4);
2  Number five = Number(5);
3
4  // Wouldn't it be wonderful if we could do the following
5  Number nine = four + five;
```

- Adding two numbers may make intuitive sense, but `Number` is a class. What does it mean to add two classes together?
  - For our `Number` class, you may be able to imagine what this would mean

- But what about for a car? What about for a bank account?
- Most of the operators we have used thus far can be *overloaded*
  - `+`, `-`, `==`, `/`, `*`, `++`, `--`, `+=`, `-=`, `*=`, `/=` can all be overloaded
  - We cannot overload the `::` and `.` operators
- These operators are all just functions, but we have to list their arguments differently than what we are used to
- Operators are defined as *friend* functions, typically with **const** argument parameters

```
1 friend Number operator +(const Number& left, const Number& right);
2
3 friend bool operator ==(const Number& left, const Number& right);
```

### Number overloaded operator example

- This example shows how to overload a number of operators

#### Example OperatorDriver.cpp

```
1 // OperatorDriver.cpp : Defines the entry point for the console
  application.
2 //
3
4 #include <iostream>
5 #include <cstdlib>
6
7 #include "Number.h"
8
9 int main(int argc, char* argv[])
10 {
11     using namespace std;
12     using namespace cs52;
13
14     Number four = Number( 4 );
15     Number five = Number( 5 );
16
17     cout << "----9----" << endl;
18     Number nine = four + five;
19     nine.printRomanNumeral();
20
21     cout << "----1----" << endl;
22     Number one = five - four;
```

```
23     one.printRomanNumeral();
24
25     if (four == five) {
26         cout << "four equals five" << endl;
27     }
28     else {
29         cout << "four does not equal five" << endl;
30     }
31
32     return( 0 );
33 }
```

### Example Number.h

```
1  #ifndef NUMBER_H
2  #define NUMBER_H
3
4  #include <iostream>
5  #include <cstdlib>
6
7  namespace cs52 {
8
9      class Number {
10     public:
11         Number();
12         Number( int initValue );
13
14         void setValue( int v );
15         int  getValue() const;
16         void printRomanNumeral() const;
17
18         friend Number operator + ( const Number& left, const Number& right
19             );
20         friend Number operator - ( const Number& left, const Number& right
21             );
22         friend bool  operator ==( const Number& left, const Number& right
23             );
24         friend Number operator / ( const Number& left, const Number& right
25             );
26         friend Number operator * ( const Number& left, const Number& right
27             );
28     };
29 }
```

```
24 private:
25     int value;
26 };
27
28 }
29
30 #endif
```

### Example Number.cpp

```
1  #include <iostream>
2  #include <cstdlib>
3
4  #include "Number.h"
5
6  namespace cs52 {
7
8  // note the friend operator functions are not member functions
9  // note the use of the const modifier
10 Number operator+ ( const Number& left, const Number& right ) {
11     Number temp = Number( left.value + right.value );
12     return( temp );
13 }
14
15 Number operator- ( const Number& left, const Number& right ) {
16     Number temp = Number( left.value - right.value );
17     return( temp );
18 }
19
20 Number operator/ ( const Number& left, const Number& right ) {
21     Number temp = Number( left.value / right.value );
22     return( temp );
23 }
24
25 Number operator* ( const Number& left, const Number& right ) {
26     Number temp = Number( left.value * right.value );
27     return( temp );
28 }
29
30 bool operator== ( const Number& left, const Number& right ) {
31     return( left.value == right.value );
32 }
```

```
33
34 Number::Number() {
35     value = 0;
36 }
37
38 Number::Number( int initValue ) {
39     value = initValue;
40 }
41
42 void Number::setValue( int v ) {
43     value = v;
44 }
45
46 // note the use of the const modifier
47 int Number::getValue() const {
48     return( value );
49 }
50
51 // note the use of the const modifier
52 void Number::printRomanNumeral() const {
53     // uses cout
54     int remainder = value;
55     int thousands = remainder / 1000;
56     remainder -= thousands * 1000;
57     int fivehundreds = remainder / 500;
58     remainder -= fivehundreds * 500;
59     int hundreds = remainder / 100;
60     remainder -= hundreds * 100;
61     int fiftys = remainder / 50;
62     remainder -= fiftys * 50;
63     int tens = remainder / 10;
64     remainder -= tens * 10;
65     int fives = remainder / 5;
66     remainder -= fives * 5;
67     int ones = remainder;
68
69     int i;
70
71     for (i = 1; i <= thousands; ++i)
72         cout << "M";
73     if (fivehundreds == 1 && hundreds == 4) {
74         cout << "CM";
75         fivehundreds = 0;
```

```
76     hundreds = 0;
77 }
78 for (i = 1; i <= fivehundreds; ++i)
79     cout << "D";
80 if (hundreds == 4) {
81     cout << "CD";
82     hundreds = 0;
83 }
84 for (i = 1; i <= hundreds; ++i)
85     cout << "C";
86 if (fiftys == 1 && tens == 4) {
87     cout << "XC";
88     fiftys = 0;
89     tens = 0;
90 }
91 for (i = 1; i <= fiftys; ++i)
92     cout << "L";
93 if (tens == 4) {
94     cout << "XL";
95     tens = 0;
96 }
97 for (i = 1; i <= tens; ++i)
98     cout << "X";
99 if (fives == 1 && ones == 4) {
100     cout << "IX";
101     ones = 0;
102     fives = 0;
103 }
104 for (i = 1; i <= fives; ++i)
105     cout << "V";
106 if (ones == 4) {
107     cout << "IV";
108     ones = 0;
109 }
110 for (i = 1; i <= ones; ++i)
111     cout << "I";
112 cout << endl;
113 }
114
115 }
```

## Overloading << and >>

- `cout` and `cin` use these operators to print information to the screen and extract information from user input
- For our number class, it may look like this:

```
1 friend ostream& operator <<(ostream& outs, const Number& n);
2
3 friend istream& operator >>(istream& ins, Number& n);
```

## Example InsertExtract.cpp

```
1 // InsertExtract.cpp : Defines the entry point for the console
  application.
2 //
3
4 #include <iostream>
5 #include <cstdlib>
6
7 #include "Number.h"
8
9 int main(int argc, char* argv[])
10 {
11     using namespace std;
12     using namespace cs52;
13
14     Number four = Number( 4 );
15     Number five = Number( 5 );
16     Number n;
17
18     cout << "----9----" << endl;
19     cout << four + five;
20
21     cout << "Enter an integer:";
22     cin >> n;
23     cout << "-----" << endl;
24     cout << n;
25
26     return( 0 );
27 }
```

**Example Number.h**

```
1  #ifndef NUMBER_H
2  #define NUMBER_H
3
4  #include <iostream>
5  #include <cstdlib>
6
7  namespace cs52 {
8
9  class Number {
10 public:
11     Number();
12     Number( int initValue );
13
14     void setValue( int v );
15     int  getValue() const;
16     // instead of using cout, accept an ostream
17     void printRomanNumeral( ostream& outs ) const;
18
19     friend Number operator + ( const Number& left, const Number& right
20                               );
21     friend Number operator - ( const Number& left, const Number& right
22                               );
23     friend bool  operator ==( const Number& left, const Number& right
24                               );
25     friend Number operator / ( const Number& left, const Number& right
26                               );
27     friend Number operator * ( const Number& left, const Number& right
28                               );
29
30     friend std::ostream& operator <<( std::ostream& outs, const Number&
31                                       n );
32     friend std::istream& operator >>( std::istream& ins, Number& n );
33
34 private:
35     int value;
36 };
37
38 }
```



**Example Number.cpp**

```
1  #include <iostream>
2  #include <cstdlib>
3
4  #include "Number.h"
5  using namespace std;
6
7  namespace cs52 {
8
9  // note the friend operator functions are not member functions
10 // note the use of the const modifier
11 ostream& operator <<( ostream& outs,
12                      const Number& n ) {
13     n.printRomanNumeral( outs );
14     return( outs );
15 }
16
17 istream& operator >>( istream& ins,
18                      Number& n ) {
19     int i = 0;
20     ins >> i;
21     n.setValue( i );
22     return( ins );
23 }
24
25 Number operator+ ( const Number& left, const Number& right ) {
26     Number temp = Number( left.value + right.value );
27     return( temp );
28 }
29
30 Number operator- ( const Number& left, const Number& right ) {
31     Number temp = Number( left.value - right.value );
32     return( temp );
33 }
34
35 Number operator/ ( const Number& left, const Number& right ) {
36     Number temp = Number( left.value / right.value );
37     return( temp );
38 }
39
40 Number operator* ( const Number& left, const Number& right ) {
41     Number temp = Number( left.value * right.value );
```

```
42     return( temp );
43 }
44
45 bool operator==( const Number& left, const Number& right ) {
46     return( left.value == right.value );
47 }
48
49 Number::Number() {
50     value = 0;
51 }
52
53 Number::Number( int initValue ) {
54     value = initValue;
55 }
56
57 void Number::setValue( int v ) {
58     value = v;
59 }
60
61 // note the use of the const modifier
62 int Number::getValue() const {
63     return( value );
64 }
65
66 // note the use of the const modifier
67 void Number::printRomanNumeral( ostream& outs ) const {
68     // uses cout
69     int remainder = value;
70     int thousands = remainder / 1000;
71     remainder -= thousands * 1000;
72     int fivehundreds = remainder / 500;
73     remainder -= fivehundreds * 500;
74     int hundreds = remainder / 100;
75     remainder -= hundreds * 100;
76     int fiftys = remainder / 50;
77     remainder -= fiftys * 50;
78     int tens = remainder / 10;
79     remainder -= tens * 10;
80     int fives = remainder / 5;
81     remainder -= fives * 5;
82     int ones = remainder;
83
84     int i;
```

```
85
86     for (i = 1; i <= thousands; ++i)
87         outs << "M";
88     if (fivehundreds == 1 && hundreds == 4) {
89         outs << "CM";
90         fivehundreds = 0;
91         hundreds = 0;
92     }
93     for (i = 1; i <= fivehundreds; ++i)
94         outs << "D";
95     if (hundreds == 4) {
96         outs << "CD";
97         hundreds = 0;
98     }
99     for (i = 1; i <= hundreds; ++i)
100         outs << "C";
101     if (fiftys == 1 && tens == 4) {
102         outs << "XC";
103         fiftys = 0;
104         tens = 0;
105     }
106     for (i = 1; i <= fiftys; ++i)
107         outs << "L";
108     if (tens == 4) {
109         outs << "XL";
110         tens = 0;
111     }
112     for (i = 1; i <= tens; ++i)
113         outs << "X";
114     if (fives == 1 && ones == 4) {
115         outs << "IX";
116         ones = 0;
117         fives = 0;
118     }
119     for (i = 1; i <= fives; ++i)
120         outs << "V";
121     if (ones == 4) {
122         outs << "IV";
123         ones = 0;
124     }
125     for (i = 1; i <= ones; ++i)
126         outs << "I";
127     outs << endl;
```

```
128 }  
129  
130  
131 }
```