Overloaded Operators, and Arrays in Classes

Modified from Sections 11.2, 11.3

The Money Class Example & Type Conversion with Constructors

Modified from Section 11.2

Program Example: The Money Class

- Display 11.3 demonstrates a class called Money
  - U.S. currency is represented
  - Value is implemented as an integer representing the value as if converted to pennies
    - An integer allows exact representation of the value
    - Type long is used to allow larger values
  - Two friend functions, equal and add, are used

Display 11.3 (1 – 5)

Display 11.3 (1/5)

Money Class—Version 1 (*part 1 of 5*)

```
//Program to demonstrate the class Money.
#include <iostream>
#include <cstdlib>
#include <cctype>
using namespace std;

//Class for amounts of money in U.S. currency.
class Money
{
public:
    friend Money add(Money amount1, Money amount2);
    //Precondition: amount1 and amount2 have been given values.
    //Returns the sum of the values of amount1 and amount2.

    friend bool equal(Money amount1, Money amount2);
    //Precondition: amount1 and amount2 have been given values.
    //Returns true if the amount1 and amount2 have the same value;
    //otherwise, returns false.

    Money(long dollars, int cents);
    //Initializes the object so its value represents an amount with the
    //dollars and cents given by the arguments. If the amount is negative,
    //then both dollars and cents must be negative.

    Money(long dollars);
    //Initializes the object so its value represents $dollars.00.

    Money( );
    //Initializes the object so its value represents $0.00.

    double get_value( );
    //Precondition: The calling object has been given a value.
    //Returns the amount of money recorded in the data of the calling object.

    void input(istream& ins);
    //Precondition: If ins is a file input stream, then ins has already been
    //connected to a file. An amount of money, including a dollar sign, has been
    //entered in the input stream ins. Notation for negative amounts is -$100.00.
    //Postcondition: The value of the calling object has been set to
    //the amount of money read from the input stream ins.
```

Money Class—Version 1 (*part 2 of 5*)

```
    void output(ostream& outs);
    //Precondition: If outs is a file output stream, then outs has already been
    //connected to a file.
    //Postcondition: A dollar sign and the amount of money recorded
    //in the calling object have been sent to the output stream outs.
private:
    long all_cents;
};

int digit_to_int(char c);
//Function declaration for function used in the definition of Money::input:
//Precondition: c is one of the digits '0' through '9'.
//Returns the integer for the digit; for example, digit_to_int('3') returns 3.

int main( )
{
    Money your_amount, my_amount(10, 9), our_amount;
    cout << "Enter an amount of money: ";
    your_amount.input(cin);
    cout << "Your amount is ";
    your_amount.output(cout);
    cout << endl;
    cout << "My amount is ";
    my_amount.output(cout);
    cout << endl;

    if (equal(your_amount, my_amount))
        cout << "We have the same amounts.\n";
    else
        cout << "One of us is richer.\n";
    our_amount = add(your_amount, my_amount);
    your_amount.output(cout);
    cout << " + ";
    my_amount.output(cout);
    cout << " equals ";
    our_amount.output(cout);
    cout << endl;
    return 0;
}
```

Money Class—Version 1 (*part 3 of 5*)

```
Money add(Money amount1, Money amount2)
{
    Money temp;

    temp.all_cents = amount1.all_cents + amount2.all_cents;
    return temp;
}

bool equal(Money amount1, Money amount2)
{
    return (amount1.all_cents == amount2.all_cents);
}

Money::Money(long dollars, int cents)
{
    if(dollars*cents < 0) //If one is negative and one is positive
    {
        cout << "Illegal values for dollars and cents.\n";
        exit(1);
    }
    all_cents = dollars*100 + cents;
}

Money::Money(long dollars) : all_cents(dollars*100)
{
    //Body intentionally blank.
}

Money::Money( ) : all_cents(0)
{
    //Body intentionally blank.
}

double Money::get_value( )
{
    return (all_cents * 0.01);
}
```

Display 11.3 (3/5)

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Money Class—Version 1 (*part 4 of 5*)

```
//Uses iostream, cctype, cstdlib:
void Money::input(istream& ins)
{
    char one_char, decimal_point,
         digit1, digit2; //digits for the amount of cents
    long dollars;
    int cents;
    bool negative;//set to true if input is negative.

    ins >> one_char;
    if (one_char == '-')
    {
        negative = true;
        ins >> one_char; //read '$'
    }
    else
        negative = false;
    //if input is legal, then one_char == '$'

    ins >> dollars >> decimal_point >> digit1 >> digit2;

    if ( one_char != '$' || decimal_point != '.'
         || !isdigit(digit1) || !isdigit(digit2) )
    {
        cout << "Error illegal form for money input\n";
        exit(1);
    }
    cents = digit_to_int(digit1)*10 + digit_to_int(digit2);

    all_cents = dollars*100 + cents;
    if (negative)
        all_cents = -all_cents;
}
```

Display 11.3 (4/5)

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Money Class—Version 1 (*part 5 of 5*)

```
//Uses cstdlib and iostream:
void Money::output(ostream& outs)
{
    long positive_cents, dollars, cents;
    positive_cents = labs(all_cents);
    dollars = positive_cents/100;
    cents = positive_cents%100;

    if (all_cents < 0)
        outs << "-$" << dollars << '.';
    else
        outs << "$" << dollars << '.';

    if (cents < 10)
        outs << '0';
    outs << cents;
}

int digit_to_int(char c)
{
    return ( int(c) - int('0') );
}
```

Sample Dialogue

```
Enter an amount of money: $123.45
Your amount is $123.45
My amount is $10.09
One of us is richer.
$123.45 + $10.09 equals $133.54
```

Display 11.3 (5/5)

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Automatic Type Conversion

- With the right constructors, the system can do type conversions for your classes
  - This code actually works

    ```
    Money base_amount(100, 60), full_amount;
    full_amount = add(base_amount, 25);
    ```

  - The integer 25 is converted to type Money so it can be added to base_amount!
  - How does that happen?

Type Conversion Event

- When the compiler sees add(base_amount, 25), it first looks for an add function that has an integer as the second parameter
  - If it exists, it might look like this
    Money add(const Money& amount1, const int amount2);
- When the appropriate definition is not found, the compiler looks for a constructor that takes one integer type parameter
  - The constructor Money(long dollars) converts 25 to a Money object so the two values can be added!

Overloading Operators

Modified from Section 11.2

Overloading Operators

- In the Money class, function add was used to add two objects of type Money
- In this section we will see how to use the '+' operator to make this code legal:

```
Money total, cost, tax;
…
total = cost + tax;
// instead of  total = add(cost, tax);
```

Operators As Functions

- An operator is a function used differently than an ordinary function
  - An ordinary function call enclosed its arguments in parenthesis

    add(cost, tax)
  - With a binary operator, the arguments are on either side of the operator

    cost + tax

Operator Overloading

- Operators can be overloaded
- The definition of operator + for the Money class is nearly the same as member function add
- To overload the + operator for the Money class
  - Use the name + in place of the name add
  - Use keyword **operator** in front of the +
  - Example:
    Money **operator +** (const Money& amount1, const Money& amount2) {…}

Operator Overloading Restrictions

- At least one argument of an overloaded operator must be of a class type.
- Only built-in operators can be overloaded, new operators cannot be created.
- The number of arguments, precedence, and associativity of an operator cannot be changed.
- The overloads of operators && and || lose short-circuit evaluation.

Operator Overloading Restrictions

- The operators :: (scope resolution), . (member access), .* (member access through pointer to member), and ?: (ternary conditional) cannot be overloaded.
- Assignment (=), subscript ([]), function call (“()”), and member selection (->) operators must be defined as member functions.

Program Example: Overloading Operators

- The Money class with overloaded operators + and == is demonstrated in

Display 11.5 (1)

Display 11.5 (2)

Display 11.5 (1/2)

DISPLAY 11.5 Overloading Operators *(part 1 of 2)*

```
1  //Program to demonstrate the class Money. (This is an improved version of
2  //the class Money that we gave in Display 11.3 and rewrote in Display 11.4.)
3  #include <iostream>
4  #include <cstdlib>
5  #include <cctype>
6  using namespace std;
7
8  //Class for amounts of money in U.S. currency.
9  class Money
10 {
11 public:
12     friend Money operator +(const Money& amount1, const Money& amount2);
13     //Precondition: amount1 and amount2 have been given values.
14     //Returns the sum of the values of amount1 and amount2.

15     friend bool operator ==(const Money& amount1, const Money& amount2);
16     //Precondition: amount1 and amount2 have been given values.
17     //Returns true if amount1 and amount2 have the same value;
18     //otherwise, returns false.

19     Money(long dollars, int cents);

20     Money(long dollars);

21     Money( );

22     double get_value( ) const;

23     void input(istream& ins);

24     void output(ostream& outs) const;
25 private:
26     long all_cents;
27 };
```

Some comments from Display 11.4 have been omitted to save space in this book, but they should be included in a real program.

<Any extra function declarations from Display 11.3 go here.>

```
28 int main( )
29 {
30     Money cost(1, 50), tax(0, 15), total;
31     total = cost + tax;

32     cout << "cost = ";
33     cost.output(cout);
34     cout << endl;
```

DISPLAY 11.5 Overloading Operators *(part 2 of 2)*

```
35      cout << "tax = ";
36      tax.output(cout);
37      cout << endl;
38      cout << "total bill = ";
39      total.output(cout);
40      cout << endl;
41      if (cost == tax)
42          cout << "Move to another state.\n";
43      else
44          cout << "Things seem normal.\n";
45      return 0;
46  }
47
48  Money operator +(const Money& amount1, const Money& amount2)
49  {
50      Money temp;
51      temp.all_cents = amount1.all_cents + amount2.all_cents;
52      return temp;
53  }
54
55  bool operator ==(const Money& amount1, const Money& amount2)
56  {
57      return (amount1.all_cents == amount2.all_cents);
58  }
59
```

<The definitions of the member functions are the same as in Display 11.3 except that *const* is added to the function headings in various places so that the function headings match the function declarations in the preceding class definition. No other changes are needed in the member function definitions. The bodies of the member function definitions are identical to those in Display 11.3.>

Output

```
cost = $1.50
tax = $0.15
total bill = $1.65
Things seem normal.
```

Overloading Unary Operators

- Unary operators take a single argument
- The unary – operator is used to negate a value

$$x = -y$$

- ++ and -- are also unary operators
- Unary operators can be overloaded
  - The Money class of Display 11.6 can include
    - A binary – operator
    - A unary – operator

Display 11.6

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DISPLAY 11.6 Overloading a Unary Operator

```
1  //Class for amounts of money in U.S. currency.
2  class Money
3  {
4  public:
5      friend Money operator +(const Money& amount1, const Money& amount2);
6      friend Money operator -(const Money& amount1, const Money& amount2);
7      //Precondition: amount1 and amount2 have been given values.
8      //Returns amount 1 minus amount2.
9      friend Money operator -(const Money& amount);
10     //Precondition: amount has been given a value.
11     //Returns the negative of the value of amount.
12     friend bool operator ==(const Money& amount1, const Money& amount2);
13     Money(long dollars, int cents);
14     Money(long dollars);
15     Money( );
16     double get_value( ) const;
17     void input(istream& ins);
18     void output(ostream& outs) const;
19 private:
20     long all_cents;
21 };
```

This is an improved version of the class `Money` *given in Display 11.5.*

We have omitted the `include` *directives and some of the comments, but you should include them in your programs.*

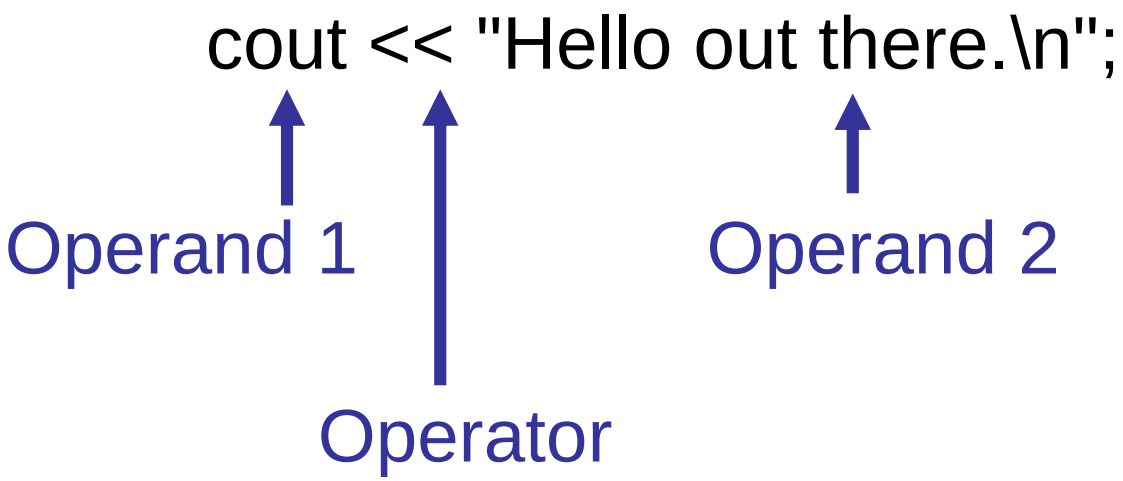
<Any additional function declarations as well as the main part of the program go here.>

```
22 Money operator -(const Money& amount1, const Money& amount2)
23 {
24     Money temp;
25     temp.all_cents = amount1.all_cents - amount2.all_cents;
26     return temp;
27 }
28 Money operator -(const Money& amount)
29 {
30     Money temp;
31     temp.all_cents = -amount.all_cents;
32     return temp;
33 }
```

<The other function definitions are the same as in Display 11.5.>

Overloading << and >>

- The insertion operator << is a binary operator
  - The first operand is the output stream
  - The second operand is the value following <<



Replacing Function output

- Overloading the << operator allows us to use << instead of Money's output function
  - Given the declaration: Money amount(100);
    amount.output(cout);

    can become

    cout << amount;

What Does << Return?

- Because << is a binary operator
  cout << "I have " << amount << " in my purse.";

  seems as if it could be grouped as
  ((cout << "I have") << amount) << "in my purse.";

- To provide cout as an argument for << amount,
  (cout << “I have”) must return cout

Overloaded << Declaration

- Based on the previous example, << should return its first argument, the output stream
  - This leads to a declaration of the overloaded << operator for the Money class:

```
class Money
{
   public:
            …
      friend ostream& operator << (ostream& outs,
                                   const Money& amount);
            …
```

Overloaded << Definition

- The following defines the << operator
  - ostream& operator <<(ostream& outs, const Money& amount)
    {
    <Same as the body of Money::output in Display 11.3 (except all_cents is replaced with amount.all_cents) >
    return outs;
    }

Return ostream& ?

- The & means a reference is returned
  - So far all our functions have returned values
- The value of a stream object is not so simple to return
  - The value of a stream might be an entire file, the keyboard, or the screen!
- We want to return the stream itself, not the value of the stream
- The & means that we want to return the stream, not its value

Overloading >>

- Overloading the >> operator for input is very similar to overloading the << for output
  - >> could be defined this way for the Money class
  - istream& operator >>(istream& ins, Money& amount);
    {
    <This part is the same as the body of Money::input in Display 11.3 (except that all_cents is replaced with amount.all_cents)>
    return ins;
    }

Display 11.8 (1-4)

Display 11.8 (1/4)

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DISPLAY 11.8 Overloading << and >> *(part 1 of 4)*

```
1   //Program to demonstrate the class Money.
2   #include <iostream>
3   #include <fstream>
4   #include <cstdlib>
5   #include <cctype>
6   using namespace std;
7
8   //Class for amounts of money in U.S. currency.
9   class Money
10  {
11  public:
12      friend Money operator +(const Money& amount1, const Money& amount2);
13      friend Money operator -(const Money& amount1, const Money& amount2);
14      friend Money operator -(const Money& amount);
15      friend bool operator ==(const Money& amount1, const Money& amount2);
```

This is an improved version of the class Money that we gave in Display 11.6.

Although we have omitted some of the comments from Displays 11.5 and 11.6, you should include them.

(continued)

DISPLAY 11.8 **Overloading << and >>** *(part 2 of 4)*

```
16      Money(long dollars, int cents);
17      Money(long dollars);
18      Money( );
19      double get_value( ) const;
20      friend istream& operator >>(istream& ins, Money& amount);
21      //Overloads the >> operator so it can be used to input values of type Money
22      //Notation for inputting negative amounts is as in -$100.00.
23      //Precondition: If ins is a file input stream, then ins has already been
24      //connected to a file.
25      friend ostream& operator <<(ostream& outs, const Money& amount);
26      //Overloads the << operator so it can be used to output values of type Money
27      //Precedes each output value of type Money with a dollar sign.
28      //Precondition: If outs is a file output stream,
29      //then outs has already been connected to a file.
30  private:
31      long all_cents;
32  };
33  int digit_to_int(char c);
34  //Used in the definition of the overloaded input operator >>.
35  //Precondition: c is one of the digits '0' through '9'.
36  //Returns the integer for the digit; for example, digit_to_int('3') returns 3.
37
38  int main( )
39  {
40      Money amount;
41      ifstream in_stream;
42      ofstream out_stream;
43
44      in_stream.open("infile.dat");
45      if (in_stream.fail( ))
46      {
47          cout << "Input file opening failed.\n";
48          exit(1);
49      }
50
51      out_stream.open("outfile.dat");
52      if (out_stream.fail( ))
53      {
54          cout << "Output file opening failed.\n";
55          exit(1);
56      }
57
```

(continued)

Display 11.8(2/4)

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DISPLAY 11.8 **Overloading << and >>** *(part 3 of 4)*

```
58      in_stream >> amount;
59      out_stream << amount
60                 << " copied from the file infile.dat.\n";
61      cout << amount
62           << " copied from the file infile.dat.\n";
63
64      in_stream.close( );
65      out_stream.close( );
66
67      return 0;
68  }
69  //Uses iostream, cctype, cstdlib:
70  istream& operator >>(istream& ins, Money& amount)
71  {
72      char one_char, decimal_point,
73           digit1, digit2; //digits for the amount of cents
74      long dollars;
75      int cents;
76      bool negative;//set to true if input is negative.

77      ins >> one_char;
78      if (one_char == '-')
79      {
80          negative = true;
81          ins >> one_char; //read '$'
82      }
83      else
84          negative = false;
85      //if input is legal, then one_char == '$'

86      ins >> dollars >> decimal_point >> digit1 >> digit2;

87      if ( one_char != '$' || decimal_point != '.'
88           || !isdigit(digit1) || !isdigit(digit2) )
89      {
90          cout << "Error illegal form for money input\n";
91          exit(1);
92      }

93      cents = digit_to_int(digit1)*10 + digit_to_int(digit2);

94      amount.all_cents = dollars*100 + cents;
95      if (negative)
96          amount.all_cents = -amount.all_cents;
```

(continued)

DISPLAY 11.8 **Overloading << and >>** *(part 4 of 4)*

```
97      return ins;
98  }
99
100 int digit_to_int(char c)
101 {
102     return ( static_cast<int>(c) - static_cast<int>('0') );
103 }
104 //Uses cstdlib and iostream:
105 ostream& operator <<(ostream& outs, const Money& amount)
106 {
107     long positive_cents, dollars, cents;
108     positive_cents = labs(amount.all_cents);
109     dollars = positive_cents/100;
110     cents = positive_cents%100;
111
112     if (amount.all_cents < 0)
113         outs << "-$" << dollars << '.';
114     else
115         outs << "$" << dollars << '.';
116
117     if (cents < 10)
118         outs << '0';
119     outs << cents;
120
121     return outs;
122 }
123
```

<The definitions of the member functions and other overloaded operators go here.
See Display 11.3, 11.4, 11.5, and 11.6 for the definitions.>

infile.dat
(Not changed by program.)

```
$1.11 $2.22
$3.33
```

outfile.dat
(After program is run.)

```
$1.11 copied from the file infile.dat.
```

Screen Output

```
$1.11 copied from the file infile.dat.
```

Arrays and Classes

Modified from Section 11.3

Arrays and Classes

- Arrays can use classes as their base types
  - Example: Money amounts[10];
  - When an array of classes is declared, the default constructor is called to initialize the indexed variables
- When an array's base type is a class…
  - Use the dot operator to access the members of an indexed variable
  - Example:

```
for (i = 0; i < 10; i++)
{
        cout << amounts[i].get_value();
        …
}
```

Arrays as Class Members

- A structure can contain an array as a member
- Example: class TemperatureList includes an array
  - The array, named list, contains temperatures
  - Member variable size is the number of items stored
  - class TemperatureList

```
{
    public:
        TemperatureList( );
        //Member functions
    private:
        double list [MAX_LIST_SIZE];
        int size;
}
```

Accessing Array Elements

- To access the array elements within a class
  - Use the dot operator to identify the array within the class
  - Use the [ ]'s to identify the indexed variable desired
  - Example: tmplist.list[i]
    references the i-th indexed variable of the variable time in tmplist (a TemperatureList)

Overview of TemperatureList

- To create an object of type TemperatureList:
  - TemperatureList my_data;
- To add a temperature to the list:
  - My_data.add_temperature(77);
    - A check is made to see if the array is full
- << is overloaded so output of the list is
  - cout << my_data;

Display 11.10 (1-2)

Display 11.10 (1/2)

DISPLAY 11.10 Program for a Class with an Array Member *(part 1 of 2)*

```
1  //This is a definition for the class
2  //TemperatureList. Values of this type are lists of Fahrenheit temperatures.
3
4  #include <iostream>
5  #include <cstdlib>
6  using namespace std;
7
8  const int MAX_LIST_SIZE = 50;
9
10 class TemperatureList
11 {
12   public:
13      TemperatureList( );
14      //Initializes the object to an empty list.
15
16      void add_temperature(double temperature);
17      //Precondition: The list is not full.
18      //Postcondition: The temperature has been added to the list.
19
20      bool full( ) const;
21      //Returns true if the list is full; false otherwise.
22
23      friend ostream& operator <<(ostream& outs,
24                                  const TemperatureList& the_object);
25      //Overloads the << operator so it can be used to output values of
26      //type TemperatureList. Temperatures are output one per line.
27      //Precondition: If outs is a file output stream, then outs
28      //has already been connected to a file.
29   private:
30      double list[MAX_LIST_SIZE]; //of temperatures in Fahrenheit
31      int size; //number of array positions filled
32 };
33
34 //This is the implementation for the class TemperatureList.
35
36 TemperatureList::TemperatureList( ) : size(0)
37 {
38     //Body intentionally empty.
39 }
```

(continued)

Display 11.10 (2/2)

DISPLAY 11.10 Program for a Class with an Array Member *(part 2 of 2)*

```
40  void TemperatureList::add_temperature(double temperature)
41  {//Uses iostream and cstdlib:
42      if ( full( ) )
43      {
44          cout << "Error: adding to a full list.\n";
45          exit(1);
46      }
47      else
48      {
49          list[size] = temperature;
50          size = size + 1;
51      }
52  }
53  bool TemperatureList::full( ) const
54  {
55       return (size == MAX_LIST_SIZE);
56  }
57  //Uses iostream:
58  ostream& operator <<(ostream& outs, const TemperatureList& the_object)
59  {
60     for (int i = 0; i < the_object.size; i++)
61          outs << the_object.list[i] << " F\n";
62      return outs;
63  }
```