

Operator Overloading, Lists and Templates

Week 6

Gaddis: 14.5, 16.2-16.4

CS 5301
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Operator Overloading

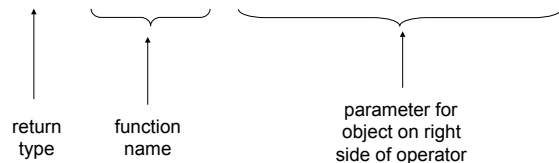
- Operators such as =, +, <, ... can be defined to work for objects of a programmer-defined class
- The function names are `operator` followed by the operator symbol:
`operator+` to define the + operator, and
`operator=` to define the = operator
- Otherwise they are like normal member functions:
 - Prototype goes in the class declaration
 - Function definition goes in implementation file

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Overloaded Operator Prototype

- Prototype:

```
int operator-(const Time &right);
```



- Pass by constant reference
 - › Does NOT copy the argument as pass-by-value does
 - › But does not allow the function to change its value
 - › (so it's like pass by value without the copying).
 - › **optional** for overloading operators

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Invoking an Overloaded Operator

- Operator functions can be invoked (called) as a regular member function:

```
int minutes = object1.operator-(object2);
```

- They can also be invoked using the more conventional syntax for operators:

```
int minutes = object1 - object2;
```

This is the main reason to overload operators, so you can use this syntax for objects of your class

- Both call the same function `operator-`, from the perspective of `object1` (`object2` is the argument).

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Example: minus for Time objects

- I decide I want `time1-time2` to be an int, equal to the number of minutes between the times.

```
class Time {
private:
    int hour, minute;
public:
    int operator- (const Time &right);
};

int Time::operator- (const Time &right) {
//Note: 12%12 = 0
    return (hour%12)*60 + minute -
        ((right.hour%12)*60 + right.minute);
}

//in a driver:
Time time1(12,20), time2(4,40);
int minutesDiff = time2 - time1;
cout << minutesDiff << endl;
```

Subtraction

Output: 260

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Overloading + for Time

```
class Time {
private:
    int hour, minute;
public:
    Time operator+ (Time right);
};

Time Time::operator+ (Time right) { //Note: 12%12 = 0
    int totalMin = (hour%12)*60 + (right.hour%12)*60
        + minute + right.minute;
    int h = totalMin / 60;
    h = h%12; //keep it between 0 and 11
    if (h==0) h = 12; //convert 0:xx to 12:xx
    Time result(h, totalMin % 60);
    return result;
}

//in a driver:
Time t1(12,5);
Time t2(2,50);
Time t3 = t1+t2;
t3.display();
```

Output: 2:55

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Overloading == and < for Time

```
bool Time::operator==(Time right) {
    if (hour == right.hour &&
        minute == right.minute)
        return true;
    else
        return false;
}

bool Time::operator< (Time right) {
    if (hour == right.hour)
        return (minute < right.minute);
    return (hour%12) < (right.hour%12);
}

//in a driver:
Time time1(12,20), time2(12,21);
if (time1<time2) cout << "correct" << endl;
if (time1==time2) cout << "correct again"<< endl;
```

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The List Type

- A List is an ordered collection of items of some type T:
 - each element has a position in the list
 - duplicate elements are allowed
- List is not a C++ data type. It is abstract/conceptual. It can be implemented in various ways (using arrays, STL vectors, linked lists...)
- We will implement using arrays, but we want to be able to use the same code for a List of int, a List of string, a List of float, etc.

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The List Type: operations

- Common operations for lists:
 - create an empty list
 - `void add(T item)`: add item to end of the list.
 - `int size()`: returns the number of items in the list.
 - `void set(int pos, T item)`: change value of item in position pos to item (if $pos \geq 0$ and $pos < size$).
 - `T get(int pos)`: return the item at position pos (if $pos \geq 0$ and $pos < size$).
 - `bool isEmpty()`: true if the list is empty
 - `bool contains(T item)`: true if item is in the list
 - `void remove(T item)`: removes item from the list.

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Templates: Type independence

- Many functions, like finding the maximum of an array, do not depend on the data type of the elements.
- We would like to re-use the same code regardless of the item type...
- **without** having to maintain duplicate copies:
 - `maxIntArray (int a[]; int size)`
 - `maxFloatArray (float a[]; int size)`
 - `maxCharArray (char a[]; int size)`

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Generic programming

- Writing functions and classes that are type-independent is called generic programming.
- These functions and classes will have one (or more) extra parameter to represent the specific type of the components.
- When the stand-alone function is called the programmer provides the specific type:

```
max<string>(array, size);
```

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Templates

- C++ provides templates to implement generic stand-alone functions and classes.
- A function template is not a function, it is a design or pattern for a function.
- The function template makes a function when the compiler encounters a call to the function.
 - Like a macro, it substitutes appropriate type

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Example function template swap

```
template <class T>
void swap (T &lhs, T &rhs) {
    T tmp = lhs;
    lhs = rhs;
    rhs = tmp;
}

int main() {
    int x = 5;
    int y = 7;
    string a = "hello";
    string b = "there";
    swap <int> (x, y);    //int replaces T
    swap <string> (a, b); //string replaces T
    cout << x << " " << y << endl;
    cout << a << " " << b << endl;
}
```

Output:

```
7 5
there hello
```

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Notes about C++ templates

- The template prefix: `template <class T>`
 - `class` is a keyword. You could also use `typename`: `template <typename T>`
- T is the parameter name. You can call it whatever you like.
 - it is often capitalized (because it is a type)
 - names like T and U are often used
- The parameter name (T in this case) can be replaced **ONLY** by a type.

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Example class template vector: class decl

```
// A barebones implementation of the List abstract data type

template <class T>
class SimpleVector {
private:
    T *aptr;           // To point to the allocated array
    int arraySize;    // Number of elements in the array
public:
    SimpleVector()      { aptr = NULL; arraySize = 0;}
    SimpleVector(int,T);
    SimpleVector(const SimpleVector &);
    ~SimpleVector();
    int size() const    { return arraySize; }
    T getElement(int position);
    void setElement(int position, T item);
};
```

Note: **not ALL types**
should be replaced by
the type variable T

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Example class template constructor, copy constructor

```
template <class T>
SimpleVector<T>::SimpleVector(int s, T item) {
    arraySize = s;
    if (arraySize > 0)
        aptr = new T [s];
    for (int count = 0; count < arraySize; count++)
        *(aptr + count) = item;
}

template <class T>
SimpleVector<T>::SimpleVector(const SimpleVector &obj) {
    arraySize = obj.arraySize;
    if (arraySize > 0)
        aptr = new T [arraySize];
    for(int count = 0; count < arraySize; count++)
        *(aptr + count) = *(obj.aptr + count);
}
```

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Example class template destructor, getElement, setElement

```
template <class T>
SimpleVector<T>::~SimpleVector() {
    if (arraySize > 0)
        delete [] aptr;
}

template <class T>
T SimpleVector<T>::getElement(int position){
    assert (0 <= position && position < arraySize);
    return aptr[position];
}

template <class T>
void SimpleVector<T>::setElement(int position, T item) {
    assert (0 <= position && position < arraySize);
    aptr[position] = item;
}
```

assert(e): if e is false, it causes the execution of the program to stop (exit). Requires #include<cassert>

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Example class template using vector

```
int main() {
    SimpleVector<string> strV(2,"");
    strV.setElement(0,"one");
    strV.setElement(1,"two");
    SimpleVector<int> intV(2,0);
    intV.setElement(0,1);
    intV.setElement(1,2);
    for (int i=0; i<2; i++) {
        cout << strV.getElement(i) << endl;
        cout << intV.getElement(i) << endl;
    }
}
```

Output:

```
one
1
two
2
```

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Class Templates and .h files

- Template classes cannot be compiled separately
 - When a file using (instantiating) a template class is compiled, it requires the **complete** definition of the template, including the function definitions.
 - Therefore, for a class template, the class declaration AND function definitions must go in the header file.
 - It is still good practice to define the functions outside of (after) the class declaration.

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