Overloading & Polymorphism

Overloading is considered “ad-hoc” polymorphism.

Can define new meanings (functions) of operators for specific types.

Compiler recognizes which implementation to use by signature (the types of operands used in the expression).

Overloading is already supported for many built-in types and operators:

\[
17 \times 42 \\
4.3 \times 2.9 \\
\text{cout} \ll 79 \ll 'a' \ll "overloading is profitable" \ll \text{endl};
\]

The implementation used depends upon the types of operands.
Reasons for Overloading

Support natural, suggestive usage:

Complex A(4.3, -2.7), B(1.0, 5.8);
Complex C;
C = A + B; // '+' means addition for this type as well

Semantic integrity (assignment for objects with dynamic content must ensure a proper deep copy is made).

Uniformity with built-in types (??)
Able to use objects in situations expecting primitive values
Operators That Can Be Overloaded

Only the following operator symbols can be overloaded:

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<th>−</th>
<th>*</th>
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<td>[]</td>
<td>()</td>
<td>new</td>
<td>new[]</td>
<td>delete</td>
<td>delete[]</td>
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**Rule:** if you don’t know what it means, don’t overload it!
Syntax for Overloading Operators

Declared and defined like other methods or functions, except that the keyword `operator` is used.

As method of the `Name` class:

```cpp
bool Name::operator==(const Name& RHS) {
    return ((First + Middle + Last) ==
             (RHS.First + RHS.Middle + RHS.Last));
}
```

As nonmember friend function:

```cpp
bool operator==(const Name& LHS, const Name& RHS) {
    return ((LHS.First + LHS.Middle + LHS.Last) ==
             (RHS.First + RHS.Middle + RHS.Last));
}
```

It is probably most natural here to use the member operator approach.
If `Name::operator==` defined as *member* function, then

```
    nme1 == nme2
```

is the same as

```
    nme1.operator==(nme2)
```

If `operator==` defined as *nonmember* function, then

```
    nme1 == nme2
```

is the same as

```
    operator==(nme1, nme2)
```

No self-respecting C++ programmer would use either of these forms.
Binary Member Operators

A class member subtract operator for Complex objects:

```cpp
Complex Complex::operator-(const Complex& RHS) const {
    return ( Complex(Real - RHS.Real, Imag - RHS.Imag) );
}
```

To be a class member, the left operand of an operator must be an object of the class type:

```cpp
Complex X(4.1, 2.3), Y(-1.2, 5.0);
OK: X + Y
Not OK: cout << X;
```

It is typical to pass by constant reference to avoid the overhead of copying the object.
Multiple Overloading

We can have two addition operators in a class:

```cpp
Complex Complex::operator+(double RHS) const {
    return (Complex(Real + RHS, Imag));
}
```

This lets us write mixed expressions, like:

```cpp
Complex X(4.1, 2.3);
double R = 1.9;
Complex Y = X + R;  // Y.Real is 6.0
```

Signature of function used to resolve which is used:

```cpp
Complex Z = Y + R;  // complex plus double
Complex W = Y + X;  // complex plus complex
```
Overloading Resolution

The compiler looks for a matching implementation of ‘+’ in this order:

Member operator in X of form:

```cpp
?? X::operator +(Y)
```

Nonmember operator of form:

```cpp
?? operator +(X,Y)
```

The return type is not part of the lookup process.
Provide a Reasonable Set of Operators

In some cases, whole categories of operators make sense for a type.

For instance, it makes sense to overload all of the arithmetic operators for the class Complex. It also makes sense to overload all six relational operators for the class Name.

Often the implementation of one operator can "piggyback" off of another:

```cpp
Complex Complex::operator+=(const Complex& RHS) {
    *this = *this + RHS; // uses overloaded '+'
    return (*this);
}
```
Unary Operators

A negation operator for the Complex class:

```cpp
Complex Complex::operator-() const {
    return ( Complex(-Real, -Imag) );
}
```

Note the use of the unary – operator for the built-in type double.

Complex A(4.1, 3.2);  // A = 4.1 + 3.2i
Complex B = -A;       // B = -4.1 - 3.2i

Note that a unary member operator takes NO parameters.
Prefix and Postfix Operators

A member prefix increment operator for the Complex class:

```cpp
Complex Complex::operator++() {
    ++Real;
    return Complex(Real, Imag);
}
```

A member postfix increment operator for the Complex class:

```cpp
Complex Complex::operator++(int Dummy) {
    Real++;
    return Complex(Real-1, Imag);
}
```

The parameter is necessary to make the signature of the postfix operator different from that of the prefix operator. Note the difference in the returned objects.
Binary Non-Member Operators

A non-member subtract operator for Complex objects:

Complex operator-(const Complex& LHS, const Complex& RHS) {
    return ( Complex(LHS.getReal() - RHS.getReal(),
                      LHS.getImag() - RHS.getImag()) );
}

As a non-member, this subtract operator must use the public interface to access the private data members of its parameters…

… unless the class Complex declares it to be a friend.

If an operator or function is declared to be a friend of a class then it can access private members as if it were a member function. However, it is poor design to grant friend access unless there is a compelling need.

Here, there is no such need. The member operator is preferred.
When to use Non-member Operators

For operators on primitive data types, such as:

```cpp
Complex operator+(int LHS, const Complex& RHS);
```

When the source for the left operand of a binary operator is not available for modification:

E.g., `ostream`

For some type casting operations:

E.g.,

```cpp
Complex::operator double() const {
    return ( R );
}
```
Granting an Operator friend Status

Here, the class Complex declares a non-member arithmetic operator to be a friend:

```cpp
class Complex {
private:
  double Real;
  double Imag;
public:
  Complex();
  // . . .
  bool operator==(const Complex& RHS) const;
  // . . .
  friend Complex operator*(int LHS,
                           const Complex& RHS);
  // . . .
};
```

The granting of friend status must be in the class declaration.
The keyword is NOT also used in the implementation.

The declaration of a friend is unaffected by the access controls public and private.

Bug note: Visual C++ 6.0 does not handle friend declarations properly unless Service Pack 4 is installed.
Here, the class Complex declares a non-member arithmetic operator to be a friend:

```cpp
Complex operator *(int LHS, const Complex& RHS) {
    double prodReal = LHS * RHS.Real;
    double prodImag = LHS * RHS.Imag;
    return (Complex(prodReal, prodImag));
}
```

The accesses to private data members are now direct, even though operator* is NOT a member of the class Complex.

In general, friend status should be granted grudgingly. Most operators should be made members instead. However, this is not always possible… this is an example.
Stream I/O Operators

We do not have access to the `istream` or `ostream` class code, so we cannot make overloading of `<<` or `>>` members of those classes.

We also cannot make them members of a data class because the first parameter must then be an object of that type.

Therefore we must define `operator<<` as non-member function.

However, it must access private members of the data class, so we will typically make it a `friend` of that class. The alternative would be to have accessor functions for all the data members that will be written, and that is frequently unacceptable.

The general signature will be:

```cpp
ostream& operator<<(ostream& Out, const Data& toWrite);
```
This overloaded `operator<<` will write a nicely formatted `Complex` object to any output stream:

```cpp
ostream& operator<<(ostream& Out, const Complex& toWrite) {
    const int Precision = 2;
    const int FieldWidth = 8;
    Out << setprecision(Precision);
    Out << setw(FieldWidth) << toWrite.Real;

    if (toWrite.Imag >= 0)
        Out << " + ";
    else
        Out << " - ";

    Out << setw(FieldWidth) << fabs(toWrite.Imag);
    Out << "i";
    Out << endl;

    return Out;
}
```

The formatting settings could also be added as data members of `Complex`, or...
This overloaded operator `>>` will read a complex number formatted in the manner used by operator `<<`:

```cpp
istream& operator>>(istream& In, Complex& toRead) {
    char signOfImag;
    In >> toRead.Real;
    In >> signOfImag;
    In >> toRead.Imag;
    if (signOfImag == '-')
        toRead.Imag = -toRead.Imag;
    In.ignore(1, 'i');
    return In;
}
```

Of course, this depends on knowing exactly how the Complex objects are formatted in the input stream.

We could make this a lot more complicated if we had multiple formats to deal with.
An Array Class

class Array {
private:
    int   Capacity;    // dimension of array
    int   Usage;       // number of cells in use
    string* List;        // the list

    void ShiftTailUp(int Start);
    void ShiftTailDown(int Start);

public:
    Array(int initCapacity = 100, string Init = "");
    Array(const Array& Source);
    Array& operator=(const Array& Source);

    int getCapacity() const;
    int getUsage() const;

    bool isFull() const;
    bool isEmpty() const;

    bool Insert(const string& newValue);
    // . . . continues . . .
// . . . continued . . .

bool DeleteAtIndex(int Idx);
bool Delete(const string& toDel);

int Find(const string& toFind) const;

string& operator[](int Idx);
const string& operator[](int Idx) const;

friend ostream& operator<<(ostream& Out, const Array& toPrint);

~Array();
}
Overloading `operator[]`

The first overloading of `operator[]`:

```cpp
string& Array::operator[](int Idx) {
    assert(0 <= Idx && Idx < Capacity);
    return List[Idx];
}
```

The first is the most commonly used. It provides the functionality you'd normally expect, allowing code like:

```cpp
Array A(10);
// ...  
A[5] = "a string";
```

The operator returns a reference to an element of the array, potentially dangerous, but also useful.

However, there's an important "gotcha" with the code above…
Overloading `operator[]`

The second overloading of `operator[]`:

```cpp
const string& Array::operator[](int Idx) const {
    assert(0 <= Idx && Idx < Capacity);
    return List[Idx];
}
```

This is provided only to support cases where a constant return value is required. These are rare. Can you think of one?
Overloading Guidelines

Avoid violating expectations about the operator:

```cpp
Complex Complex::operator~() const {
    return ( Complex(Imag, Real) );
}
```

Provide a complete set of properly related operators: `a = a + b` and `a += b` have the same effect and it makes sense to support both if either is supplied.

Define the operator overload as a class member unless it's necessary to do otherwise.

If the operator overload cannot be a class member, then make it a `friend` rather than add otherwise unnecessary member accessors to the class.