CH-230-A

Programming in C and C++

C/C++

Tutorial 12

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Operator Overloading (1)

- Overloaded operators allow a different syntax for function/method calls
- Operator overloading allows the programmer to use language operators for user defined data type. For example

```
1   Car first, second, third;
2   ...
3   third = first + second;
```

  what this could mean is left to the programmer
- New operators cannot be introduced

Operator Overloading (2)

- It is possible to overload operators only for user defined data types
  - Thus it is not possible to alter the meaning of the + operator between `int`s, `float`s, and so on
    - C code should compile with C++ compilers without changing its functionality
- Overloading an operator should help the reader of the program and not the programmer
  - You can define an operator + between two instances of a salary class which subtracts them
  - Whether this makes sense or not is up to your design choices and skills

Sorting Students by Grade

With overloaded operators

```
1 Student *list;
2 ...
3 for (i = ...)
4   if (list[i] > list[j]) {
5     tmp = list[i];
6     list[i] = list[j];
7     list[j] = tmp;
8   }
9 ...
```

Without overloaded operators

```
1 Student *list;
2 ...
3 for (i = ...) {
4   if (list[i].getGrade() >
5     list[j].getGrade()) {
6     ...
7   }
8 }
9 ...
```

Which one is “cleaner”?

Using/Calling Operators

- From the previous example it should be clear that no magic things are happening, but just a compact (and clear) syntax for method calls can be used
- Whenever the compiler finds an operator involving user defined types, it verifies if it is possible to find a proper definition
- Operators are overloaded as there can be more than just one version: + between two instances of car, + between an instance of car and an instance of bike, and so on
- Types help in determining the version which should be called

Operators, Methods or `friend` Functions

- To carry out their task operators need to access class data
- Then, they have to be either methods or friend functions
  - There are some guidelines
    `Student3.h` `Student3.cpp` `studentoperator.cpp`
- It is possible to overload both unary and binary operators

Overloading the = Operator

- Overloading the = operator is fundamental if your class deals with pointers as properties
- Language provided = operator performs field to field copy
- If the class has pointers, different instances end up with sharing the same memory
  - Also, there could be memory leaks
    `charbuffer.h` `charbuffer.cpp`
- The operator = must be a method and must return a reference to the class
  - This allows iterated assignments (`a=b=c;`)

Overloadable Operators

Unary Operators	Binary Operators
`+ - & ! ~`	`+ - * / % ^ & | <<`
`++ --`	`>> += -= *= /= %= ^=`
(both prefix and postfix)	`&= |= >>= <<= == !=`
`[ ] -> ( )`	`< > <= >= && || ->*`

`new` and `delete` can be overloaded as well

What Should Operators Return?

- A reference, it they modify the involved argument(s) (like =, +=, etc.)
- Return a reference to the modified object, usually by using `this`
- A new instance if they do not modify arguments, but rather use them to produce new information (like most binary operators: +, -, etc.)
- A `bool` if it is a boolean operator

Member or `friend`?

The following table proposed in the textbook can be taken as a general guideline

Operator	Use
Unary operators	Member
`= ( ) [ ] -> ->*`	Must be member
`+= -= /= *= ^= &= |= %= >>= <<=`	Member
Other binary operators	Friend or member

`complex.h` `complex.cpp` `testcomplex2.cpp`

Overloading << and >>

- For example for the `Complex` class:

```
1     friend ostream& operator<<(ostream& out,
      const Complex &z)
2
3     friend istream& operator>>(istream& in,
      Complex &z)
```

Polymorphism

- The last cornerstone of OOP has no correspondence in non-OOP languages
- It deals with writing code which can correctly operate even with data types unknown at compile time
- Just one additional keyword, `virtual`, which offers a wide range of applications

Starting from Upcasting

- Upcasting means that a derived class can be used wherever an ancestor class is expected
  - This because the interface of the parent is inherited
- A derived class can redefine a method, i.e., it can provide a new implementation
- `randomnonvirtual.cpp`
- `randomvirtual.cpp`

What Happens?

- In the first example the redefinition of the method was not perceived, while in the second "the expected" behavior was observed
- It should be evident that at compile time there is not enough information to bind the method call to the right method to execute
  - This is called late binding

The `virtual` Keyword

- When a method is declared as `virtual`, late binding is requested
- `virtual` should be specified just in the declaration of the base class
- Late binding is inherited from there on
  - The redefinition of virtual methods is called overriding
- When dealing with virtual methods, each object carries some sort of info to make its identification possible at runtime

`virtual` and Pointers

- Be aware: the late binding feature works only if you deal with pointers to instances, and not if you directly work with instances
  - And of course, also with C++ references
- When passing objects to methods/functions, using C++ references speeds up parameters passing and enables polymorphism

The Added Value of Polymorphism

- By mean of polymorphism it is possible to write general purpose code
  - When possible, general code always deals with base classes, and calls virtual methods
- Then, the code will work even with later introduced data types (new classes)

What Should be `virtual`?

- The decision is up to the designer
  - Some languages (like Java) make all methods virtual
- Virtual method calls introduce overhead
  - Run time binding
  - Making always every method virtual is poor design
- The choice is done at the base class level
  - If a method is not virtual in the base class, it cannot be made virtual in a derived class

How Does Polymorphism Work?

- In order to correctly manage it, it is useful to know how polymorphism is implemented
  - For every class with virtual methods, a table is created; the table holds the address of the virtual methods (VTABLE)
  - In addition, a pointer to this table is stored inside the class; this pointer is invisible (VPTR)
  - When a virtual method is called, the pointer is used to access the table, and then from the table the address of the function is read
  - As each class with virtual elements is shaped this way, the compiler can insert the code to resolve the calls without knowing the type
  - The intermediate indirection through VTABLE is the reason for the slower performance of virtual method calls

Calls Through the Virtual Table

```
1  class Base {
2    public:
3      virtual void
4        method()=0;
5      // VPTR INSERTED
6  };
7  class Derived
8      : public Base {
9    public:
10     void method() { };
11     // VPTR INSERTED
12 };
13 ...
14 Base *a= new Derived;
15 a->method();
```