CPSC 427: Object-Oriented Programming

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The Many Uses of Classes

What is a class?

- A collection of things that belong together.
- A struct with associated functions.
- A way to encapsulate behavior: public interface, private implementation.
- A way to protect data integrity, providing world with functions that provide a read-only view of the data.
- A data type from which objects (instances) can be formed. We say the instances belong to the class.
- A way to organize and automate allocation, initialization, and deallocation of storage.
- A way to break a complex problem into manageable, semi-independent pieces, each with a defined interface.
- A reusable module.

Virtue Demo

Virtual virtue

```
class Basic {
public:
    virtual void print(){cout <<"I am basic.  "; }
};
class Virtue : public Basic {
public:
    virtual void print(){cout <<"I have virtue.  "; }
};
class Question : public Virtue {
public:
    void print(){cout <<"I am questing.  "; }
};
```

Main virtue

What does this do?

```
int main (void) {
    cout << "Searching for Virtue\n";
    Basic* array[3];
    array[0] = new Basic();
    array[1] = new Virtue();
    array[2] = new Question();
    array[0]->print();
    array[1]->print();
    array[2]->print();
   return 0;
}
```

See demo `18a-Virtue`!

Linear Data Structure Demo

Using polymorphism

Similar data structures:

- Linked list implementation of a stack of items.
- Linked list implementation of a queue of items.

Both support a common interface:

- `void      put(Item*)`
- `Item*     pop()`
- `Item*     peek()`
- `ostream& print(ostream&)`

They differ only in where `put()` places a new item.

The demo `18b-Virtual` (from Chapter 15 of textbook) shows how to exploit this commonality.

Interface file

We define this common interface by the pure abstract class.

```
class Container {
  public:
    virtual ~Container() {}
    virtual void     put(Item*)       =0;
    virtual Item*    pop()            =0;
    virtual Item*    peek()           =0;
    virtual ostream& print(ostream&) =0;
};
```

Any class derived from it is required to implement these four functions.

`Stack` and `Queue` could be derived directly from `Container`. Instead we exploit additional commonality between them.

Class Linear

```
class Linear: public Container {
  protected:  Cell* head;
  private:    Cell* here; Cell* prior;
  protected:  Linear();
    virtual   ~Linear ();
              void     reset();
              bool     end() const;
              void     operator ++();
    virtual   void     insert( Cell* cp );
    virtual   void     focus() = 0;
              Cell*    remove();
              void     setPrior(Cell* cp);
  public:     void     put(Item * ep);
              Item*    pop();
              Item*    peek();
    virtual   ostream& print( ostream& out );
};
```

Example: Stack

```
class Stack : public Linear {
  public:
    Stack(){}
    ~Stack(){}
    void  insert( Cell* cp ) { reset(); Linear::insert(cp); }
    void  focus(){ reset(); }

    ostream& print( ostream& out ){
        out << "  The stack contains:\n";
        return Linear::print( out );
    }
};
```

Example: Queue

```
class Queue : public Linear {
  private:
    Cell*   tail;

  public:
    Queue() { tail = head; }
    ~Queue(){}

    void  insert( Cell* cp ) {
        setPrior(tail); Linear::insert(cp); tail=cp; }
    void  focus(){ reset(); }
};
```

Class structure

Class structure.

- `Container` specifies the common interface.
- `Linear` contains the bulk of the code. It is derived from `Container`.
- `Stack` and `Queue` are both derived from `Linear`.
- `Cell` is a "helper" class that is aggregated by `Linear`.
- `Item` is the base type for the container elements. It is defined by a `typedef` here but would normally be specified by a template.
- `Exam` is a non-trivial item type used by `main` to illustrate stacks and queues.

C++ features

The demo illustrates several C++ features.

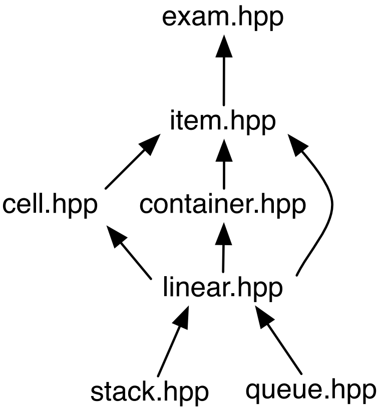
1. [`Container`] Pure abstract class.
2. [`Cell`] Friend functions.
3. [`Cell`] Printing a pointer in hex.
4. [`Cell`] Operator extension `operator Item*()`.
5. [`Linear`] Virtual functions and polymorphism.
6. [`Linear`] Scanner pairs (prior, here) for traversing a linked list.
7. [`Linear`] Operator extension `operator ++()`
8. [`Linear`, `Exam`] Use of `private, protected, and public` in same class.

#include structure

Getting `#include`'s in the right order.

Problem: Making sure compiler sees symbol definitions before they are used.

Partial solution: Make dependency graph. If not cyclic, each `.hpp` file includes the `.hpp` files just above it.



Functions Revisited

Global vs. member functions

A **global** function is one that takes zero or more *explicit* arguments.
Example: `f(a, b)` has two explicit arguments `a` and `b`.

A **member** function is one that takes an *implicit* argument along with zero or more *explicit* arguments.
Example: `c.g(a, b)` has two explicit arguments `a` and `b` and implicit argument `c`.
Example: `d->g(a, b)` has two explicit arguments `a` and `b` and implicit argument `*d`.

Note that an omitted implicit argument defaults to `(*this)`, which must make sense in the context.
Example: If `g` is a member function of class `MyClass`, then within `MyClass`, the call `g(a, b)` defaults to `(*this).g(a,b)` (or equivalently `this->g(a,b)`).

Defining global functions

There are three ways to define a global function.

1. Place the declaration at the top level of your code, outside of any class declarations. Most functions in C are of this kind.
2. Place the declaration inside a class definition, prefixed by the keyword `static`. This creates a global function whose *name* is qualified by the class name. It's visibility is controlled by the visibility keywords `public`, `protected`, and `private`.
3. Place the declaration at the top level and prefix its name by `static`. This creates a C-style static function whose name is visible only within the one compile module. Classes and static member functions provide a better way to provide modularity and control name visibility, so this should not be used in C++. It is retained only for compatibility with C.

Defining member functions

Placing a function declaration inside a class definition creates a member function.

Its definition is considered to be “inside” the class, whether or not it appears in the class or as an out-of-line function in a `.cpp` file.

Example:

```
class MyClass {
protected:
    double g(const int* a, unsigned b) const;
};
```

This defines a member function `g` with explicit parameters of type `const int*` and `unsigned` and implicit parameter of type `const MyClass&`.

Operator Extensions

Operator syntax

We have seen the `operator` keyword used to extend the meaning of operators.

Each binary operator $\oplus$ corresponds to a function whose name is `operator`$\oplus$, but the operator syntax $a \oplus b$ does not tell us whether to look for a global or a member function. Possibile meanings:

- Global function: `operator`$\oplus$`(a, b)`.
- Member function: `a.operator`$\oplus$`(b)`.

It could mean either, and the compiler sees if either one matches. If both match, it reports an ambiguity.

Operator extension as member function

Here's a sketch for how one might go about defining a complex number class.

```
class Complex {
private:
   double re;  // real part
   double im;  // imaginary part
public:
   Complex( double re, double im ) : re(re), im(im) {}
   Complex operator+(const Complex& b) const {
      return Complex( re+b.re, im+b.im );
   }
   Complex operator*(const Complex& b) const {
      return Complex( re*b.re - im*b.im, re*b.im + im*b.re );
   }
};
```

Operator extension as global function

We have seen one important example of a global operator extension when we define the output operator on a new class.

Given the choice, it is preferable to use a member operator function.

We use a global form of `operator<<` because the left hand operator is of predefined type `ostream`, and we can't add member functions to that class.

Prefix unary operator extensions

C++ has a number of prefix unary operators
`*, -, ++, new, ...`

The corresponding operator functions are
`operator*(), operator-(), operator++(),`
`operator new(), ...`

Postfix unary operator extensions

C++ also has two postfix unary operators `++, --`.

The corresponding operator functions are `operator++(int), operator--(int)`.

This is a special case that breaks all the normal rules, but it works since `++` and `--` are not binary operators. The dummy `int` parameter should be ignored.

Ambiguous operator extensions

```
class Bar {
public:
    int operator+(int y) { return y+2; }
};

int operator+(Bar& b, int y) { return y+3; }

int main() {
    Bar b;
    cout << b+5 << endl;
}
```

Compiler reports `error: ambiguous overload for 'operator+' in 'b + 5'`.

Summary: How to define operator extensions

Unary operator *op* is shorthand for `operator` *`op`* `()`.

Binary operator *op* is shorthand for `operator` *`op`* `(T arg2)`.

Some exceptions: Pre-increment and post-increment.

To define meaning of `++x` on type `T`, define `operator ++()`.

To define meaning of `x++` on type `T`, define `operator ++(int)` (a function of one argument). The argument is ignored.

Special case operator extensions

Some special cases.

- Subscript: `T& operator [](S index)`.
- Arrow: `X* operator ->()` returns pointer to a class `X` to which the selector is then applied.
- Function call; `T2 operator ()(`*arg list*`)`.
- Cast: `operator T()` defines a cast to type `T`.

Can also extend the `new`, `delete`, and `,` (comma) operators.