CPSC 427: Object-Oriented Programming

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PS6: Who prints the blockchain?

OO-design problem

In PS6, we need a function `print` that prints a blockchain.

Which class does `print` belong in? Possibilities:

- Class `Blockchain`, because Blockchain is semantically meaningful.
- Class `Block`, because to print a blockchain requires knowledge of how the chain is represented and how to go from one block to the next. That knowledge is only available in `Block`.

An analog of class demo 13-BarGraph

A `Row` is represented by a linked list of `Cells`.

This is analogous to a `Blockchain` being represented by a linked list of `Blocks`.

The `Row` print function reaches inside the Cell in order to iterate down the list of Cells.

This is possible because `Row` is a friend class of `Cell`.

Note: There is a comment in row.cpp that says,
// Design decision: print Cell data directly; no delegation of print

An analog to STL containers

Iterators (see next section) are like pointers and can be used by a client to iterate through a container such as a vector or list.

One could define a class `iterator` inside of Blockchain to allow one to iterate through a chain of blocks.

The Blockchain::print() function could then simply do

```
for(Block::iterator it=begin(); it!=end(); ++it) out<<*it;
```

Unfortunately, this would result in the blocks being printed in reverse order from what I specified in the assignment. You would need a backwards iterator, which doesn't work for singly linked lists.

In addition, iterators still do not overcome the problem of a Blockchain function needing knowledge of the structure of a Block.

A compromise

The compromise I chose for my own solution is to give `Block` two print functions:

- `print()` prints a single block.
- `printChain()` prints the whole chain of blocks. An easy recursive solution prints the chain in the right order.
- `printChain()` delegates the printing of a single block to `Block::print()`.

`Blockchain::print()` delegates the printing of the whole blockchain to `Block::printChain()`.

STL Iterators

Containers

A container stores a collection of objects of arbitrary type `T`.

The basic containers in STL are:

- `vector` – a dynamic array
- `deque` – a double-ended queue
- `list` – a doubly linked list
- `map` – an associative array of key/value pairs with unique keys
- `set` – a sorted collection of unique values
- `multimap` – an associative array of key/value pairs with duplicate keys allowed
- `multiset` – a sorted collection of values with multiplicity

Iterators

Iterators are like generalized pointers into containers.

Most pointer operations `*`, `->`, `++`, `==`, `!=`, etc. work with iterators.

- `begin()` returns an iterator pointing to the first element of the vector.
- `end()` returns an iterator pointing past the last element of the vector.

Iterator example

Here's a program to store and print the first 10 perfect squares.

```
#include <iostream>
#include <vector>
using namespace std;

int main() {
  vector<int> tbl(10);
  for (unsigned k=0; k<10; k++) tbl[k] = k*k;
  vector<int>::iterator pos;
  for (pos = tbl.begin(); pos != tbl.end(); pos++)
    cout<< *pos<< endl;
}
```

Using iterator inside a class

```
#include <iostream>
#include <vector>
using namespace std;
class Squares : vector<int> {
public:
  Squares(unsigned n) : vector<int>(n) {
    for (unsigned k=0; k<n; k++) (*this)[k] = k*k; }
  ostream& print(ostream& out) const {
    const_iterator pos;   // must be const_iterator
    for (pos=begin(); pos!=end(); pos++) out<< *pos<< endl;
    return out; }
};
int main() {
  Squares sq(10);
  sq.print(cout);
}
```

Using subscripts and size()

```
#include <iostream>
#include <vector>
using namespace std;
class Squares : vector<int> {
public:
  Squares(unsigned n) {
    for (unsigned k=0; k<n; k++) push_back(k*k); }
  ostream& print(ostream& out) const {
    for (unsigned k=0; k<size(); k++) out<< (*this)[k]<< endl;
    return out; }
};
int main() {
  Squares sq(10);
  sq.print(cout);
}
```

STL Algorithms

Algorithms

STL has algorithms as well as data structures.

You must `#include <algorithm>`.

Commonly used: `copy`, `fill`, `swap`, `max`, `min`, `max_element`, `min_element`, but there are many many more.

We'll look at `sort` in greater detail.

STL `sort` algorithm

`sort` works only on randomly-accessible containers such as `vector`. (`list` has its own sort method.)

`sort` takes two iterator arguments to designate the sort range.

It can also take an optional third "comparison" argument to define the sort order.

Reverse sort example

```
class Squares : vector<int> {
public:
  Squares(unsigned n) {
    for (unsigned k=0; k<n; k++) push_back(k*k);}

  // decreasing order; *** must be static ***
  static bool cmp( const int& x1, const int& x2 ) {
    return x1 > x2; }

  void rsort() { sort(begin(), end(), cmp); }

  ostream& print(ostream& out) const {
    for (unsigned k=0; k<size(); k++) out<< (*this)[k]<< endl;
    return out; }
};
```

Reverse sort example (cont.)

```
#include <iostream>
#include <vector>
#include <algorithm>
using namespace std;

class Squares : vector<int> {
  ...
};

int main() {
  Squares sq(10);
  sq.rsort();
  sq.print(cout);
}
```

pair<T1, T2>

A pair<T1, T2> is an ordered pair of elements of type T1 and T2, respectively.

Class pair<T1, T2> has public data members first and second.

Example:

```
pair<string, double> item("book", 49.95);
                            // makes pair <"book", 49.95>
cout<< item.first;          // prints "book"
cout<< item.second;         // prints 49.95
```

map<Key,Val>

`map<Key,Val>` associates a value with each key.

More precisely, it is an ordered collection of elements of type `pair<Key,Val>`.

You must `#include <map>`.

Can use standard subscript notation to access `map` contents, where subscript is the key.

Can also use a `map` iterator, which returns a pointer to a `pair`.

Using a map<Key,Val>

Example:

```
typedef map<string,double> myMap; // alias for convenience
myMap::iterator pos;
myMap m;                         // a map from strings to doubles
m["dog"];                        // puts pair <"dog",0.0> into m
m["bird"]=5.2;                   // puts pair <"bird",5.2> into m
pos = m.find("cat");             // returns m.end() for not found
cout<< (pos==m.end())<< endl;// prints 1 (true)
pos = m.find("bird");            // pos points to <"bird",5.2>
if (pos!=m.end()) {
  cout<< pos->first<< endl;  // prints "bird"
  cout<< pos->second<< endl; // prints 5.2;  }
}
```

Copying from one container to another

Two ways to copy multiple elements in one statement.

Suppose `m` is a map and `v` a vector of pairs compatible with `m`.

1. v.assign(m.begin(), m.end());
2. Supply `m.begin()` and `m.end()` as arguments to the `v` constructor.

Copying from map to vector of pairs

```
#include <iostream>
#include <map>
#include <vector>
#include <string>
using namespace std;
int main() {
  map<string,double> m;
  m["dog"]=3; m["cat"]=2;
  // construct p from m
  vector<pair<string,double> > p(m.begin(),m.end());
  // declare iterator
  vector<pair<string,double> >::const_iterator pos;
  // print p
  for (pos=p.begin(); pos!=p.end(); ++pos)
    cout<< pos->first<< " "<< pos->second<< endl;
}
```

string class

The standard `string` class tries to make strings behave like other built-in data types.

Like `vector<char>`, strings are growable, but they are not implemented using `vector`, and they support many special string operations.

They can be assigned (`=, assign()`), compared (`==, !=, <, <=, >, >=, compare()`), concatenated (`+`), read and written (`>>, <<`), searched (`find(), ...`), extracted (`[], substr()`), modified (`+=, append(), ...`), and more.

Their length can be found (`size(), length()`).

`s.c_str()` or `s.data()` returns a copy of `s` as a C string.

You must `#include <string>`.

Name Visibility

Private derivation (default)

`class B : A { ... };` specifies private derivation of `B` from `A`.

A class member inherited from `A` become `private` in `B`.
Like other private members, it is inaccessible outside of `B`.

If `public` in `A`, it can be accessed from within `A` or `B` or via an instance of `A`, but not via an instance of `B`.

If `private` in `A`, it can only be accessed from within `A`.
It cannot even be accessed from within `B`.

Private derivation example

Example:

```
class A {
private:  int x;
public:   int y;
};
class B : A {
    ... f() {... x++; ...} // privacy violation
};
//-------- outside of class definitions --------
A a; B b;
a.x   // privacy violation
a.y   // ok
b.x   // privacy violation
b.y   // privacy violation
```

Public derivation

`class B : public A { ... };` specifies public derivation of `B` from `A`.

A class member inherited from `A` retains its privacy status from `A`.

If `public` in `A`, it can be accessed from within `B` and also via instances of `A` or `B`.

If `private` in `A`, it can only be accessed from within `A`.
It cannot even be accessed from within `B`.

Public derivation example

Example:

```
class A {
private:  int x;
public:   int y;
};
class B : public A {
    ... f() {... x++; ...} // privacy violation
};
//-------- outside of class definitions --------
A a; B b;
a.x   // privacy violation
a.y   // ok
b.x   // privacy violation
b.y   // ok
```

The `protected` keyword

`protected` is a privacy status between `public` and `private`.

Protected class members are inaccessible from outside the class (like `private`) but accessible within a derived class (like `public`).

Example:

```
class A {
protected: int z;
};
class B : A {
    ... f() {... z++; ...} // ok
};
```

Protected derivation

`class B : protected A { ... };` specifies protected derivation of `B` from `A`.

A `public` or `protected` class member inherited from `A` becomes `protected` in `B`.

If `public` in `A`, it can be accessed from within `B` and also via instances of `A` but not via instances of `B`.

If `protected` in `A`, it can be accessed from within `A` or `B` but not from outside.

If `private` in `A`, it can only be accessed from within `A`.
It cannot be accessed from within `B`.

Surprising example 1

Link to surprising-1.cpp.

```
1   class A {
2   protected:
3     int x;
4   };
5   class B : public A {
6   public:
7     int f() { return x; }          //  ok
8     int g(A* a) { return a->x; }  //  privacy violation
9   };
```

Result:

```
tryme1.cpp: In member function 'int B::g(A*)':
tryme1.cpp:3: error: 'int A::x' is protected
tryme1.cpp:9: error: within this context
```

Surprising example 2: Contrast the following

Link to surprising-2a.cpp.

```
1   class A { };
2   class B : public A {};    // <-- public derivation
3   int main() { A* ap; B* bp;
4     ap = bp; }
```

Result: OK.

Link to surprising-2b.cpp.

```
1   class A { };
2   class B : private A {};    // <-- private derivation
3   int main() { A* ap; B* bp;
4     ap = bp; }
```

Result:

```
tryme2.cpp: In function 'int main()':
tryme2.cpp:4: error: 'A' is an inaccessible base of 'B'
```

Surprising example 3

Link to surprising-3.cpp.

```
1  class A { protected: int x; };
2  class B : protected A {};
3  int main() { A* ap; B* bp;
4    ap = bp; }
```

Result:

```
tryme3.cpp: In function 'int main()':
tryme3.cpp:4: error: 'A' is an inaccessible base of 'B'
```