

CSCI-1200 Computer Science II — Fall 2006

Lecture 9 — Associative Containers (Maps), Part 2

Review of Lecture 8

- Maps are associations between keys and values.
- Maps have fast insert, access and remove operations: $O(\log n)$, we'll learn why later in the term when we study the implementation!
- Maps store pairs; map iterators refer to these pairs.
- The primary map member functions we discussed are `operator[]`, `find`, `insert`, and `erase`.
- The choice between maps, vectors and lists is based on naturalness, ease of programming, and efficiency of the resulting program.

Today's Class — Maps, Part 2

- Maps containing more complicated values.
- Example: index mapping words to the text line numbers on which they appear.
- Maps whose keys are class objects.
- Example: maintaining student records.
- Summary discussion of when to use maps.

9.1 More Complicated Values

- Let's look at the example:

```
map<string, vector<int> > m;  
map<string, vector<int> >::iterator p;
```

Note that the space between the `> >` is **required**. Otherwise, `>>` is treated as an operator.

- Here's the syntax for entering the number 5 in the vector associated with the string "hello":

```
m[string("hello")].push_back(5);
```

- Here's the syntax for accessing the size of the vector stored in the map pair referred to by map iterator p:

```
p = m.find(string("hello"));  
p->second.size()
```

Now, if you want to access (and change) the i^{th} entry in this vector you can either use subscripting:

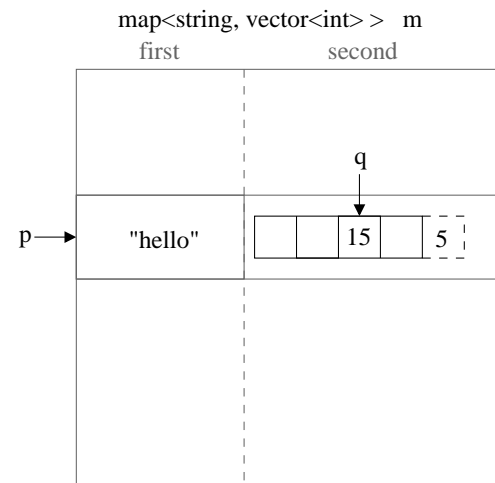
```
(p->second)[i] = 15;
```

(the parentheses are needed because of precedence) or you can use vector iterators:

```
vector<int>::iterator q = p->second.begin() + i;  
*q = 15;
```

Both of these, of course, assume that at least $i+1$ integers have been stored in the vector (either through the use of `push_back` or through construction of the vector).

- We can figure out the correct syntax for all of these by drawing pictures to visualize the contents of the map and the pairs stored in the map. We will do this during lecture, and you should do so **all the time** in practice.



9.2 Exercise

Write code to count the odd numbers stored in the map

```
map<string, vector<int> > m;
```

This will require testing all contents of each vector in the map. Try writing the code using subscripting on the vectors and then again using vector iterators.

9.3 A Word Index in a Text File

```
// Given a text file, generate an alphabetical listing of the words in the file
// and the file line numbers on which each word appears. If a word appears on
// a line more than once, the line number is listed only once.
#include <algorithm>
#include <cctype>
#include <iostream>
#include <map>
#include <string>
#include <vector>
using namespace std;

// implementation omitted, will be covered in a later lecture
vector<string> breakup_line_into_strings(const string& line);

int main() {
    map<string, vector<int> > words_to_lines;
    string line;
    int line_number = 0;

    while (getline(cin, line)) {
        line_number++;
        // Break the string up into words
        vector<string> words = breakup_line_into_strings(line);

        // Find if each word is already in the map.
        for (vector<string>::iterator p = words.begin(); p!= words.end(); ++p) {
            // If not, create a new entry with an empty vector (default) and
            // add to index to the end of the vector
            map<string, vector<int> >::iterator map_itr = words_to_lines.find(*p);
            if (map_itr == words_to_lines.end())
                words_to_lines[*p].push_back(line_number); // could use insert here
            // If it is, check the last entry to see if the line number is
            // already there. If not, add it to the back of the vector.
            else if (map_itr->second.back() != line_number)
                map_itr->second.push_back(line_number);
        }
    }

    // Output each word on a single line, followed by the line numbers.
    map<string, vector<int> >::iterator map_itr;
    for (map_itr = words_to_lines.begin(); map_itr != words_to_lines.end(); map_itr++) {
        cout << map_itr->first << ":\t";
        for (unsigned int i = 0; i < map_itr->second.size(); ++i)
            cout << (map_itr->second)[ i ] << " ";
        cout << "\n";
    }
    return 0;
}
```

9.4 Our Own Class as the Map Key

- So far we have used `string` (mostly) and `int` (once) as the key in building a `map`. Intuitively, it would seem that `string` is used quite commonly.
- More generally, we can use any class we want as long as it has an `operator<` defined on it. For example, consider:

```
class Name {
public:
    Name(const string& first, const string& last) :
        m_first(first), m_last(last) {}

    const string& first() const { return m_first; }
    const string& last() const { return m_last; }

private:
    string m_first;
    string m_last;
};
```

- Suppose we wanted a map of names and associated student records, where the student record class stores things like address, courses, grades, and tuition fees and calculates things like GPAs, credits, and remaining required courses. To make this work, we need to add an `operator<`. This is simple:

```
bool operator< (const Name& left, const Name& right) {
    return left.last() < right.last() ||
        (left.last() == right.last() && left.first() < right.first());
}
```

Now you can define a map:

```
map<Name, StudentRecord> students;
```

- Of course, you would still need to write the `StudentRecord` class!
- Also, some older compilers require the definition of `operator==` as well, so be alert to this.

9.5 Typedefs

- One of the painful aspects of using maps is the syntax. For example, consider a constant iterator in a map associating strings and vectors of ints:

```
map < string, vector<int> > :: const_iterator p;
```

- Typedefs are a syntactic means of shortening this. For example, if you place the line:

```
typedef map < string, vector<int> > map_vect;
```

before your main function (and any function prototypes), then anywhere you want the map you can just use the identifier `map_vect`:

```
map_vect :: const_iterator p;
```

The compiler makes the substitution for you.

9.6 An Additional Example: Organizing MP3's

- Let's store information about the MP3 files stored on various computers in a network,
- We'll need to dynamically update this information as computers are added to and removed from the network.
- We'd like to find songs and the fastest connection for downloading them.
- The solution stores the information in a `map`, with a unique identifier for each computer forming the "key" and a class object that maintains information about a computer and its MP3s as the "value".

9.7 MP3 class

```
class MP3 {
public:
    // CONSTRUCTORS
    MP3() {}
    MP3(const string& artist, const string& title) : artist_(artist), title_(title) {}
    // ACCESSORS
    const string& get_artist() const { return artist_; }
    const string& get_title() const { return title_; }
private:
    // REPRESENTATION
    string artist_;
    string title_;
};
```

9.8 Computer class (implementation omitted)

```
class Computer {
public:
    // CONSTRUCTOR
    Computer(double speed) : speed_(speed) { }

    // Iterate through the list of MP3, printing each.
    void print_mp3s() const;
    // Returns true if the Computer has the requested song, returns reference to song via parameter
    bool has_song(const string& artist, const string& title, MP3& requested_song) const;
    // Build a list of all songs by the indicated artist.
    list<MP3> songs_by_artist(const string& artist) const;
    double getSpeed() const { return speed_; }

    // Add an MP3 to the list of MP3s. Return false if the song is already there.
    bool add_mp3(const string& artist, const string& title);
private:
    // REPRESENTATION
    double speed_; // network connection speed in bytes per second
    list<MP3> mp3s_; // the songs on the computer; could be a vector just as easily
};
```

9.9 Exercise: Understanding the data structure

Walk through the MP3 program that follows for some sample input and draw a diagram of the resulting map data structure.

9.10 main.cpp (some parsing omitted)

```
// Each computer is identified by a unique id (a string)
typedef map<string, Computer> MP3_map;

int main() {
    MP3_map mp3_system;
    bool quit = false;
    char option;
    while (cin >> option) {
        switch (option) {
            case 'a': add_computer(mp3_system); break;
            case 'p': print_mp3s_on_computer(mp3_system); break;
            case 'f': find_song(mp3_system); break;
            case 'F': find_songs_by_artist(mp3_system); break;
            case 'q': return 1; break;
            default:
                cout << "Error: " << option << " is not a valid command" << endl;;
                break;
        }
    }
}

// Add a computer to the map of MP3's
void add_computer(MP3_map& mp3_system) {
    // READS IN: computer_id (string), speed (double),
    //           and artist (string) & title (string) for all songs

    // Try to add the computer using the map insert function.
    pair<MP3_map::iterator, bool> result_pair =
        mp3_system.insert(make_pair(computer_id, new_computer));
    assert(result_pair.second); // make sure the computer isn't already there!
    cout << "Computer " << computer_id << " added." << endl;
}

// Print the MP3's for a given computer.
void print_mp3s_on_computer(const MP3_map& mp3_system) {
    string computer_id;
    cin >> computer_id;
    MP3_map::const_iterator c_itr = mp3_system.find(computer_id);
    if (c_itr == mp3_system.end()) {
        cout << "Computer " << computer_id << " is not in the system." << endl;
    } else {
        cout << "Songs found on " << computer_id << ":\n";
        c_itr->second.print_mp3s();
    }
}

// Find all computers with a particular song.
void find_song(const MP3_map& mp3_system) {
    string artist, title;
    cin >> artist >> title;
    bool found = false;
    string computer_id;
    double speed;
    // Iterate through the map, looking for the song.
    MP3_map::const_iterator c_itr;
    for (c_itr = mp3_system.begin(); c_itr != mp3_system.end(); c_itr++) {
        MP3 request;
        if (c_itr->second.has_song(artist, title, request)) {
            if (!found || c_itr->second.getSpeed() > speed) {
                found = true;
                computer_id = c_itr->first;
                speed = c_itr->second.getSpeed();
            }
        }
    }
}
```

```

}
if (found)
    cout << "Fastest download for \"" << title << "\" by " << artist << " from " << computer_id << endl;
else
    cout << "No computer found with \"" << title << "\" by " << artist << endl;
}

```

9.11 Exercise: Find all songs by an artist

```

// Find and output information about all songs by a given artist.
void find_songs_by_artist(const MP3_map& mp3_system) {
    string artist;
    cin >> artist;

```

```

}

```

9.12 Exercise: Performance

Give the order notation of the cost of each of the operations (adding a computer, printing the mp3s stored on a particular computer, finding a song within the system, finding all songs by a particular artist). Assume there are n computers and m songs stored on each computer.

9.13 When to Use Maps, Reprise

- Maps are an association between two types, one of which (the key) must have a `operator<` ordering on it.
- The association may be immediate:
 - Words and their counts.
 - Words and the lines on which they appear
- Or, the association may be created by splitting a type:
 - Splitting off the name (or student id) from rest of student record.
 - Splitting off the computer id from the rest of the information about the computer and its MP3 files.