

CSCI-1200 Computer Science II — Spring 2006

Lecture 5 — Classes I

Review from Lecture 4

- Vectors are dynamically-sized arrays
- Vectors, strings and other containers should be:
 - passed by reference when they are to be changed, and
 - passed by constant reference when they aren't.
- If you forget the `&` and pass by value, the object will be copied which is expensive for containers with lots of elements. Note: This is unlike arrays, which are *not copied when passed by value*.
- Vectors can “contain” any type of objects, including strings and other vectors.

Today's Lecture: C++ classes

- Types and defining new types
- A `Date` class.
- Class declaration: member variables and member functions
- Using the class member functions
- Class scope
- Member function implementation
- Classes vs. structs
- Designing classes

Reading for Lectures 5 & 6: Koenig and Moo, Sections 4.2-4.4 and Chapter 9. See also Malik, Chapter 12.

5.1 Types and Defining New Types

- What is a type? It is a structuring of memory plus a set of operations (functions) that can be applied to that structured memory.
- Examples: integers, doubles, strings, and vectors.
- In many cases, when we are using a class we don't know how that memory is structured. Instead, what we really think about is the set of operations (functions) that can be applied.
- To clarify, let's focus on strings and vectors. These are classes. We'll outline what we know about them:
 - The structure of memory within each class object
 - The set of operations defined
- We are now ready to start defining our own new types using classes.

5.2 Example: A Date Class

- Many programs require information about dates.
- Information stored about the date includes the month, the day and the year.
- Operations on the date include recording it, printing it, asking if two dates are equal, flipping over to the next day (incrementing), etc.

5.3 C++ Classes

- A C++ class consists of
 - a collection of member variables, usually `private`, and
 - a collection of member functions, usually `public`, which operate on these variables.
- `public` member functions can be accessed directly from outside the class,
- `private` member functions and member variables can only be accessed indirectly, through public member functions.
- We will look at the example of the `Date` class declaration.

5.4 Using C++ classes

We have been using C++ classes (from the standard library) already this semester, so studying how the `Date` class is used is simply a review:

```
// Program:  date_main.cpp
// Purpose:  Demonstrate use of the Date class.

#include <iostream>
#include "date.h"

int main() {
    std::cout << "Please enter today's date.\n"
              << "Provide the month, day and year: ";
    int month, day, year;
    std::cin >> month >> day >> year;
    Date today( month, day, year );

    Date tomorrow( today.getMonth(), today.getDay(), today.getYear() );
    tomorrow.increment();

    std::cout << "Tomorrow is ";
    tomorrow.print();
    std::cout << std::endl;

    Date Sallys_Birthday(9,29,1995); // call a different constructor
    if ( sameDay( tomorrow, Sallys_Birthday) ) {
        std::cout << "Hey, tomorrow is Sally's birthday!\n";
    }

    std::cout << "The last day in this month is " << today.lastDayInMonth() << std::endl;
    return 0;
}
```

- **Important:** Each object we create of type `Date` has its own distinct member variables.
- Calling class member functions for class objects using the “dot” notation. For example, `tomorrow.increment()`;
- Note: after looking at the example, we still will not have examined how the class member functions are implemented! This is an important feature of class design.

5.5 Exercise

Add code to `date_main.cpp` to read in another date, check if it is a leap-year, and check if it is equal to `tomorrow`. Output appropriate messages based on the results of the checks.

5.6 Class Implementation: date.h & date.cpp

A class implementation usually consists of 2 files. First we'll look at the *header file* date.h

```
// File:    date.h
// Purpose: Header file with declaration of the Date class, including
//          member functions and private member variables.

class Date {
public:
    Date();
    Date(int aMonth, int aDay, int aYear);

    // Assignment and change
    void setDay( int aDay );
    void setMonth( int aMonth );
    void setYear( int aYear );
    void increment();

    // Access individual values
    int getDay() const;
    int getMonth() const;
    int getYear() const;

    // Functions that answer questions about a Date object
    bool isEqual(const Date& date2) const;    // same day, month, year?
    bool isLeapYear() const;
    int  lastDayInMonth() const;
    bool isLastDayInMonth() const;

    // Output as month/day/year
    void print() const;

private: // Member variables
    int day;
    int month;
    int year;
};

bool sameDay( const Date &date1, const Date &date2 );
```

And here is the other part of the class implementation, the *implementation file* date.cpp

```
// File:    date.cpp
// Purpose: Implementation file for the Date class.

#include <iostream>
#include "date.h"

using namespace std;

// array to figure out the number of days, it's used by the auxiliary function daysInMonth
const int DaysInMonth[13] = {0, 31, 28, 31, 30, 31, 30, 31, 31, 30, 31, 30, 31};

Date::Date() { //default constructor
    day = 1;
    month = 1;
    year = 1900;
}

Date::Date(int aMonth, int aDay, int aYear) { // construct from month/day/year
    month = aMonth;
    day = aDay;
    year = aYear;
}
```

```

void Date::setDay(int d) {
    day = d;
}

void Date::setMonth(int m) {
    month = m;
}

void Date::setYear(int y) {
    year = y;
}

void Date::increment() {
    if ( !isLastDayInMonth() ) {
        day++;
    } else {
        day = 1;
        if ( month == 12 ) { // December
            month = 1;
            year ++ ;
        } else {
            month ++ ;
        }
    }
}

int Date::getDay() const {
    return day;
}

int Date::getMonth() const {
    return month;
}

int Date::getYear() const {
    return year;
}

bool Date::isEqual(const Date& date2) const {
    return day == date2.day && month == date2.month && year == date2.year;
}

bool Date::isLeapYear() const {
    return ( year%4 ==0 && year % 100 != 0) || year%400 == 0;
}

int Date::lastDayInMonth() const {
    if ( month == 2 && isLeapYear() )
        return 29;
    else
        return DaysInMonth[ month ];
}

bool Date::isLastDayInMonth() const {
    return day == lastDayInMonth(); // uses member function
}

void Date::print() const {
    std::cout << month << "/" << day << "/" << year;
}

bool sameDay( const Date& date1, const Date& date2 ) {
    return date1.getDay() == date2.getDay() && date1.getMonth() == date2.getMonth();
}

```

5.7 Class scope notation

- `Date::` indicates that what follows is within the scope of the class.
- Within class scope, the member functions and member variables are accessible without the name of the object.

5.8 Constructors

These are special functions that initialize the values of the member variables. You have already used constructors for string and vector objects.

- The syntax of the call to the constructor mixes variable definitions and function calls. (See `date_main.cpp`)
- “Default constructors” have no arguments.
- Multiple constructors are allowed, just like multiple functions with the same name are allowed. The compiler determines which one to call based on the types of the arguments (just like any other function call).
- When a new object is created, *EXACTLY one constructor for the object is called*.

5.9 Member Functions

Member functions are like ordinary functions except:

- They can access and modify the object’s member variables.
- They can call the member functions without using an object name.
- Their syntax is slightly different because they are defined within class scope.

For the `Date` class:

- `set` and `get` functions access and change a day, month or year.
- The `increment` member function uses another member function, `isLastDayInMonth`.
- `isEqual` accepts a second `Date` object and then accesses its values directly using the dot notation. Since we are inside class `Date` scope, this is allowed. The name of the second object, `date2`, is required to indicate that we are interested in its member variables.
- `lastDayInMonth` uses the `const` array defined at the start of the `.cpp` file.

More on member functions:

- When the member variables are *private*, the only means of accessing them and changing them from outside the class is through member functions.
- If member variables are made *public*, they can be accessed directly. This is usually considered bad style and will not be allowed in this course.
- Functions that are not members of the `Date` class must interact with `Date` objects through the class public members (a.k.a., the “public interface” declared for the class). One example is the function `sameDay` which accepts two `Date` objects and compares them by accessing their day and month values through their public member functions.

5.10 Header Files (.h) and Implementation Files (.cpp)

The code for the `Date` example is in three files:

- The *header file*, `date.h`, contains the class declaration.
- The *implementation file*, `date.cpp`, contains the member function definitions. Note that `date.h` is included.
- `date_main.cpp` contains the code outside the class. Again `date.h` again is included.
- The files `date.cpp` and `date_main.cpp` are compiled separately and then linked to form the executable program.
- Different organizations of the code are possible, but not preferable. For example, we could have combined `date.h` and `date.cpp` into a single file and included it in the main program. In this case, we would not have to compile two separate files.
- In many large projects, programmers establish follow a convention with two files per class, one header file and one implementation file.

5.11 Constant member functions

Member functions that do not change the member variables should be declared `const`

- For example: `bool Date::isEqual(const Date &date2) const;`
- This must appear consistently in **both** the member function declaration in the class declaration (in the `.h` file) and in the member function definition (in the `.cpp` file).
- `const` objects (usually passed into a function as parameters) can **ONLY** use `const` member functions. *Remember, you should only pass objects by value under special circumstances. In general, pass them by const reference if you don't want them to change.*
- While you are learning, you will probably make errors in determining which member functions should or should not be `const`. Watch for compile errors.

5.12 Exercise

Add a member function to the `Date` class to add a given number of days to the `Date` object. The number should be the only argument and it should be an unsigned int. Should this function be `const`?

5.13 Classes vs. structs

- The textbook introduces `structs` in Chapter 4 and `classes` in Chapter 9. We've taken a different approach.
- Technically, a `struct` is a `class` where the default protection is `public`, not `private`.
 - As mentioned above, when a member variable is `public` it can be accessed and changed directly using the dot notation: `tomorrow.day = 52;` We can see immediately that this is dangerous because a day of 52 is invalid!
- The usual practice of using `struct` is all public members and no member functions. The example in Sections 4.2-4.4 illustrates this. This practice is contrary to the usual conventions of C++ programming, as discussed in Chapter 9.

Rule for the duration of CS II: We will not allow the use of `struct`, and no member variable can be made public. This will be enforced with various levels of grading penalties.

5.14 C++ vs. Java Classes

- In C++, classes have sections labeled `public` and `private`, but there can be multiple public and private sections. In Java, each individual item is tagged public or private.
- Class declarations and class definitions are separated in C++, whereas they are together in Java.
- In C++ there is a semi-colon at the very end of the class declaration (after the `}`).

5.15 Designing and implementing classes

This takes a lot of practice, but here are some ideas to start from:

- Begin by outlining what the class objects should be able to do. This gives a start on the member functions.
- Outline what member variables might be needed to accomplish this.
- Write a draft class declaration in a `.h` file.
- Write code that uses the member functions. Revise the class `.h` file as necessary.
- Write the class `.cpp` file that implements the member functions.

In general, don't be afraid of major rewrites if you find a class isn't working correctly or isn't as easy to use as you intended. This happens frequently in practice!

5.16 Exercise

What happens if the user inputs `2 30 2006` into the program? How would you modify the `Date` class to make sure *illegal dates* are not created?