Structures and Classes

CS 16: Solving Problems with Computers I
Lecture #15

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WHAT THE NEXT 3 WEEKS LOOK LIKE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
20-Nov	21-Nov	22-Nov	23-Nov	24-Nov
Lab 8 issued	***Lecture:*** Dynamic Arrays, Makefiles			
27-Nov	28-Nov	29-Nov	30-Nov	1-Dec
Lab 9 issued	***Lecture:*** Structures and Classes	Lab8 due	***Lecture:*** Linked Lists	
	Hw 8 due			
	Hw 9 issued			
4-Dec	5-Dec	6-Dec	7-Dec	8-Dec
Lab attendance is optional	***Lecture:*** Recursion, Search/Sort	Lab 9 due	***Lecture:*** Review for Final Exam	
			Hw 9 due	
11-Dec	12-Dec	13-Dec	14-Dec	15-Dec
	FINAL EXAM, 4 - 7 PM			

Lecture Outline

- **Structures (Ch. 10.1)**
- Defining structures
- Member variables and functions
- Structures in functions
- Hierarchy in structures
- Initializing structures

- **Classes (Ch. 10.2)**
- Defining member functions and the **::** operator
- Public vs. Private members
- Constructors

What Is a Class?

- A ***class*** is a data type whose variables are called ***objects***
- Some pre-defined data types you have used are: int, char, double
- Some pre-defined classes you have used are: ifstream, string, vector
- You can also define your own classes as well

Class Definitions

- To define a "class", we need to…
  - Describe the **kinds of values** the variable can hold
    - Numbers? Characters? *Both*? Something else?
  - Describe the **member functions**
    - What can we do with these values?

- We will start by defining ***structures*** as a first step toward defining classes

STRUCTURES

Structures

- A structure's use can be viewed as an **object**
- Let's say it does not contain any member functions (for now…)
- It does contain multiple values of possibly different types
- We'll call these **member variables**

Structures

- These multiple values are logically related to one another and come together as a single item
  - Examples:
    A bank Certificate of Deposit (CD) which has the following values:
    a balance
    an interest rate
    a term (how many months to maturity)

    What kind of values should these be?!

  - A student record which has the following values:
    the student's ID number
    the student's last name
    the student's first name
    the student's GPA

    What kind of values should these be?!

The CD Structure Example: Definition

- The Certificate of Deposit structure can be defined as

```
struct CDAccount
{
    double balance;          // a dollar amount
    double interest_rate;    // a percentage
    int term;                // a term amount in months
} ;
```

Remember this semicolon!

- Keyword **`struct`** begins a structure definition
- **`CDAccount`** is the structure ***tag*** – this is the structure's **type**
- Member names are ***identifiers*** declared in the braces

Using the Structure

- Structure definition should be placed ***outside*** any function definition
  - Including outside of **main( )**
  - This makes the structure type available to all code that follows the structure definition

- To declare two variables of type **CDAccount**:

```
CDAccount  my_account, your_account;
```

`my_account` and `your_account`
contain distinct member variables **balance**, **interest_rate**, and **term**

Specifying Member Variables

- Member variables are specific to the structure variable in which they are declared
- Syntax to specify a member variable (note the '.')
  Structure_Variable_Name . Member_Variable_Name
- Given the declaration:

```
CDAccount  my_account, your_account;
```

- Use the **dot operator** to specify a member variable, e.g.

```
my_account.balance          is a double
my_account.interest_rate    is a double
my_account.term             is an int
```

```
//Program to demonstrate the CDAccount structure type.
#include <iostream>
using namespace std;

//Structure for a bank certificate of deposit:
struct CDAccount
{
    double balance;
    double interest_rate;
    int term;//months until maturity
};

void get_data(CDAccount& the_account);
//Postcondition: the_account.balance and the_account.interest_rate
//have been given values that the user entered at the keyboard.
```

Note the struct definition is placed before main()

```
int main( )
{
    CDAccount account;
    get_data(account);

    double rate_fraction, interest;
    rate_fraction = account.interest_rate/100.0;
    interest = account.balance*rate_fraction*(account.term/12.0);
    account.balance = account.balance + interest;

    cout.setf(ios::fixed);
    cout.setf(ios::showpoint);
    cout.precision(2);
    cout << "When your CD matures in "
         << account.term << " months,\n"
         << "it will have a balance of $"
         << account.balance << endl;
    return 0;
}
```

Note the declaration of CDAccount

Note the calculations done with the structure's member variables

Note that the structure is passed into the function as call-by-reference. You can also pass a structure call-by-value.

```
//Uses iostream:
void get_data(CDAccount& the_account)
{
    cout << "Enter account balance: $";
    cin >> the_account.balance;
    cout << "Enter account interest rate: ";
    cin >> the_account.interest_rate;
    cout << "Enter the number of months until maturity\n"
         << "(must be 12 or fewer months): ";
    cin >> the_account.term;
}
```

Note the use of the structure's member variables with an input stream.

Sample Dialogue

```
Enter account balance: $100.00
Enter account interest rate: 10.0
Enter the number of months until maturity
(must be 12 or fewer months): 6
When your CD matures in 6 months,
it will have a balance of $105.00
```

Duplicate Names

- Member variable names duplicated between structure types are **not** a problem

```
struct FertilizerStock
{
    double quantity;
    double nitrogen_content;
};

FertilizerStock  super_grow;
```

```
struct CropYield
{
   int quantity;
   double size;
};

CropYield  apples;
```

- This is because we have to use the dot operator
- **super_grow.quantity** and **apples.quantity** are different variables stored in different locations in computer memory

Structures as Return Function Types

- Structures **can also** be the type of a value ***returned*** by a function

Example:

```
CDAccount shrink_wrap
            (double the_balance, double the_rate, int the_term)
{
    CDAccount temp;
    temp.balance = the_balance;
    temp.interest_rate = the_rate;
    temp.term = the_term;
    return temp;
}
```

What is this function doing?

Example: Using Function **shrink_wrap**

- **shrink_wrap** builds a complete structure value in the structure **temp**, which is returned by the function

- We can use **shrink_wrap** to give a variable of type **CDAccount** a value in this way:

```
CDAccount  new_account;
new_account = shrink_wrap(1000.00, 5.1, 11);
```

Assignment and Structures

- The assignment operator (=) can also be used to give values to structure types
- Using the CDAccount structure again for example:

```
CDAccount my_account, your_account;
my_account.balance = 1000.00;
my_account.interest_rate = 5.1;
my_account.term = 12;
your_account = my_account;
```

- Note: This last line assigns *all member variables* in **your_account** the corresponding values in **my_account**

Hierarchical Structures

- Structures **can** contain member variables that are **also structures**

```
struct Date
{
    int month;
    int day;
    int year;
};
```

```
struct PersonInfo
{
    double height;
    int weight;
    Date birthday;
};
```

- struct **PersonInfo** contains a **Date** structure

Using **PersonInfo**

*An example on "." **operator** use*

```
struct PersonInfo
{
    double height;
    int weight;
    Date birthday;
};
```

```
struct Date
{
   int month;
   int day;
   int year;
};
```

- A variable of type **PersonInfo** is declared:

```
PersonInfo person1;
```

- To display the birth year of **person1**,
  first access the birthday member of person1

```
cout <<  person1.birthday…(wait! not complete yet!)
```

- But we want the ***year***, so we now specify the year member of the birthday member

```
cout << person1.birthday.year;
```

Initializing Structures

- A structure can be initialized when declared

Example:

```
struct Date
{
      int month;
      int day;
      int year;
};
```

- Can be initialized in this way – watch for the order!:

```
Date due_date = {4, 20, 2018};
Date birthday = {12, 25, 2000};
```

CLASSES

Main Differences: **structure** vs **class**

- *Classes* in C++ evolved from the concept of *structures* in C
- Both *classes* and *structures* **can have member variables**
- Both *classes* and *structures* **can have member functions**,
  ALTHOUGH classes are made to be easier to use with member functions
- Classes may not be used when interfacing with C,
  because C does not have a concept of classes (only structures)

Example of a Class: **DayOfYear** Definition

```
class DayOfYear
    {
      public:
        void output( );
        int month;
        int day;
    };
```

Member Function **Declaration**

Member Variables **Declaration**

public vs private settings for members

public *means these members can be accessed by a program*

private *means they are only for use by the class itself (e.g. test code)*

Defining a Member Function

- Member functions are ***declared*** in the class declaration
- Member function ***definitions*** identify class in which the function is a member
  - Note the use of the **::** in the following example

- Member function *definition* syntax:

```
Returned_Type Class_Name::Function_Name(Parameter_List)
{
        Function Body Statements
}
```

Defining a Member Function

- Member function *definition* syntax:

```
Returned_Type Class_Name::Function_Name(Parameter_List)
{
        Function Body Statements
}
```

EXAMPLE:

```
void DayOfYear::output()
{
   cout  << "month = "  << month << ",  day = " << day << endl;
}
```

The '::' Operator

- '**::**' is called the ***scope resolution operator***
- Indicates ***what class*** a member function is a member of
- Example:
  `void DayOfYear::output( )` indicates that function `output` is a member of the `DayOfYear` class
- The class name that *precedes* '**::**' is called a ***type qualifier***

'::' Operator vs. '.' Operator

- '::' is used with *classes* to identify a member

```
void DayOfYear::output( )
   {
     // function body
   }
```

- '.' is used with *variables* to identify a member

```
DayOfYear birthday;
birthday.output( );
```

Calling Member Functions

- Calling the **DayOfYear** member function output:

```
DayOfYear today, birthday;
today.output( );
birthday.output( );
```

Note that **today** and **birthday** have their own versions of the month and day variables for use by the output function

- Also, note how similar this is to other class member functions call-outs that we've done, such as:

```
string Name = "Jimbo Jones";
int stlen = Name.length( );
```

Member Variables/Functions

Private vs. Public

- C++ can help us by restricting the program from directly referencing certain member variables
- ***Private*** members of a class can only be referenced *within* the definitions of member functions and **NOT** by outside users of the class
- If the program tries to access a private member, the compiler will give an error message
- Private is the default setting in classes

Public Variables

- Public variables are the only ones that can be accessed directly by the main program
- If we want the program to be able to change a class' variables' values, then they **must** be declared as **public**

Public or Private Members

- The keyword **private** identifies the members of a class that can be accessed *only by member functions* of the class
  - Members that follow the keyword **private** are called *private members* of the class

- The keyword **public** identifies the members of a class that can be accessed *from outside the class*
  - Members that follow the keyword **public** are called *public members* of the class

Example

```
class DayOfYear {
   public:
      void input();
      void output();
   private:
      void check_results();
      int var1, var2;
   …
   …
};
```

The member functions **input( )** and **output( )** are accessible from the **main( )** or other functions.

The member function **check_results()** is strictly to be used internally in **DayOfYear** class workings, as are int variables **var1** and **var2**.

Example from the Textbook: *Display 10.4*

- The program takes in user input on today's date and compares it to J.S. Bach's birthday (i.e. a specific date of 3/21)

- Utilizes a user-defined class called **DayOfYear** which holds a date and a month, but ALSO does functions like:
  - Input date
  - Check date against set birthday
  - Outputs results

The **main( )** function

```
int main () {
    DayOfYear today, bach_birthday;
    cout << "Enter today's date:\n";
    today.input();
    cout << "Today's date is: ";
    today.output();

    bach_birthday.set(3, 21);
    cout << "Bach's Birthday is: ";
    bach_birthday.output();

    if ((today.get_month() == bach_birthday.get_month()) &&
         (today.get_day() == bach_birthday.get_day()) {
        cout << "Happy Birthday, J.S. Bach!!!\n"; }

    return 0; }
```

*Note "today" & "bach_birthday" are both **objects** of the **class** DayOfYear*

*.input() and .output() are member functions of DayOfYear class. **Must be public b/c main() is using them.***

*.set() is a **public** member function too.*

*.get_month() and get_day() are **public** member functions too.*

What variable types do they look like they return?

DayOfYear Class Definition

```
class DayOfYear
{
   public:
      void input();
      void output();
      void set(int newmonth, int newday);
      int get_month();
      int get_day();
   private:
      void check_date();
      int month, day;
   …
   …
}
```

Q:
Why didn't we see the member function ***check_date( )*** *or the member variables* ***month*** *or* ***day*** *in the main( ) part of the program?*

A: They're ***private****!*

Define All The Member Functions…

input()

```
void input() {




}
```

STOP!!!

Define All The Member Functions…

input()

```
void DayOfYear::input()
{
   cout << "Enter the month as a number: ";
   cin >> month;
   cout << "Enter the day of the month: ";
   cin >> day;

   check_date();
}
```

Calling a member function!

*Is this a **private** or a **public** one?*

Define All The Member Functions…

output()

```
void DayOfYear::output()
{

   cout << “Month is: ”;
   cout << month << endl;
   cout << “Day of the month is: ”;
   cout << day << endl;

}
```

Define All The Member Functions…
set(), *get_month()* and *get_day()*

```
void DayOfYear::set(int newmonth, int newday)
{
   month = newmonth;
   day = newday;
   check_date();
}

int DayOfYear::get_month()
{  return month; }

int DayOfYear::get_day()
{  return day; }
```

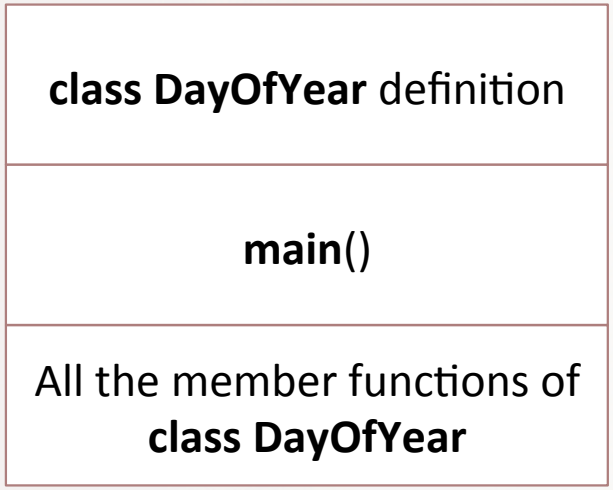
Define All The Member Functions…
check_date()

```
void DayOfYear::check_date()
{
   if ( (month < 1) || (month > 12) || (day < 1) || (day > 31) )
   {
      cout << "Illegal date. Aborting program!\n";
      exit(1);
   }

}
```

Putting It All Together

- Check Display 10.4 Example in Textbook for full program.



- Looks familiar?
- Same approach with defining functions in C++

Using Private Variables

- It is a practice norm to make all member *variables* **private**
- Although, this is not strictly required…
- Private variables require member functions to perform *all* changing and retrieving of values

Using Private Variables

- It is a practice norm to make all member *variables* **private**
- Functions that allow you to *obtain* the values of member variables are called **accessor** functions.
  - Example: **get_day** in class **DayOfYear**
- Functions that allow you to *also change* the values of member variables are called **mutator** functions.
  - Example: **set** in class **DayOfYear**

Review: Declaring an **Object**

- Once a **class** is defined, an **object** of the class is declared just as variables of any other type
  - This is similar to when you declare a structure in C++
- Example: To create two objects of type Bicycle:

```
class Bicycle
{
     // class definition lines
};

...

Bicycle my_bike,  your_bike;
```

The Assignment Operator

- Objects and structures can be assigned values with the assignment operator (=)
  - Example:

```
DayOfYear  due_date, tomorrow;

tomorrow.set(11, 19);

due_date = tomorrow;
```

Review: Calling Public Members

- Recall that if calling a member function from the main function of a program, you must include the the object name:

```
account1.update( );
```

- Again, just like when we used member functions of pre-defined classes, like **`string`**

Calling Private Members

- When a *member function* calls a **private** member function, an object name is not used

- Example: if `fraction (double percent);` is a private member of the class **BankAccount** AND if `fraction` is called by another member function called `update`

```
void BankAccount::update( )
{  balance = balance + fraction(interest_rate)* balance; }
```

NOT: ***`BankAccount::fraction(interest_rate)*balance;`***

Constructors

- A **constructor** can be used to *initialize* member variables when an object is declared
- A constructor is a *member function* that is usually public and is automatically called when an object of the class is declared
  - RULE: A constructor's name must be the **name of the class**
- A constructor cannot return a value
  - No return type, ***not even void***, is used in declaring or defining a constructor

YOUR TO-DOs

- ❑ Lab 8 due TOMORROW (Wed. 11/29) by noon
- ❑ HW 9 due Thu. 12/7
- ❑ Lab 9 due Wed. 12/6 by noon

- ❑ Read Ch. 13 on **Linked Lists** for Thursday

- ❑ Visit Prof's and TAs' office hours if you need help!
- ❑ Smile! *And make people wonder why the heck you're smiling*

</LECTURE>