Introduction to Classes and Objects

CS 110C

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Topics

- Abstract Data Types
- Object-Oriented Programming
- Introduction to Classes
- Creating and Using Objects
- Defining Member Functions
- Constructors
- Destructors
- Private Member Functions

Topics (Continued)

- Passing Objects to Functions
- Object Composition
- Separating Class Specification, Implementation, and Client Code
- Structures
- Introduction to Object-Oriented Analysis and Design
- Screen Control

Abstract Data Types

- Programmer-created data types that specify
  - legal values that can be stored
  - operations that can be done on the values
- The user of an abstract data type (ADT) does not need to know any implementation details (*e.g.*, how the data is stored or how the operations on it are carried out)

Abstraction in Software Development

- Abstraction allows a programmer to design a solution to a problem and to use data items without concern for how the data items are implemented
- This has already been encountered earlier in pow():
  - To use the **`pow`** function, you need to know what inputs it expects and what kind of results it produces
  - You do not need to know how it works

Abstraction and Data Types

- Abstraction: a definition that captures general characteristics without details

  ex: An abstract triangle is a 3-sided polygon. A specific triangle may be scalene, isosceles, or equilateral

- Data Type: defines the kind of values that can be stored and the operations that can be performed on it

Object-Oriented Programming

- Procedural programming uses variables to store data, and focuses on the processes/ functions that occur in a program. Data and functions are separate and distinct.
- Object-oriented programming is based on objects that encapsulate the data and the functions that operate on it.

Object-Oriented Programming Terminology

- **object**: software entity that combines data and functions that act on the data in a single unit
- **attributes**: the data items of an object, stored in **member variables**
- **member functions (methods)**: procedures/ functions that act on the attributes of the class

More Object-Oriented Programming Terminology

- **data hiding**: restricting access to certain members of an object. The intent is to allow only member functions to directly access and modify the object's data
- **encapsulation**: the bundling of an object's data and procedures into a single entity

Object Example

Square

Member variables (attributes) `int side;`

Member functions
`void setSide(int s)`
`{   side = s;     }`
 	
`int getSide()`
`{   return side; }`

Square object's data item: **`side`**

Square object's functions: **`setSide`** - set the size of the side of the square, **`getSide`** - return the size of the side of the square

Why Hide Data?

- Protection – Member functions provide a layer of protection against inadvertent or deliberate data corruption
- Need-to-know – A programmer can use the data via the provided member functions. As long as the member functions return correct information, the programmer needn't worry about implementation details.

Introduction to Classes

- **Class**: a programmer-defined data type used to define objects
- It is a pattern for creating objects

ex:

```
string fName, lName;
```

creates two objects of the `string` class

Introduction to Classes

- Class declaration format:

```
class className
{
    declaration;
    declaration;
};
```

Notice the required ;

Access Specifiers

- Used to control access to members of the class.
- Each member is declared to be either

  `public`: can be accessed by functions outside of the class

  or

  `private`: can only be called by or accessed by functions that are members of the class

Class Example

Access specifiers

```
class Square
{
  private:
   int side;
  public:
   void setSide(int s)
   { side = s; }
   int getSide()
   { return side; }
};
```

More on Access Specifiers

- Can be listed in any order in a class
- Can appear multiple times in a class
- If not specified, the default is **`private`**

Creating and Using Objects

- An object is an instance of a class
- It is defined just like other variables

```
Square sq1, sq2;
```

- It can access members using dot operator

```
sq1.setSide(5);
cout << sq1.getSide();
```

Types of Member Functions

- **Acessor, get, getter function**: uses but does not modify a member variable

  ex: `getSide`

- **Mutator, set, setter function**: modifies a member variable

  ex: `setSide`

Defining Member Functions

- Member functions are part of a class declaration
- Can place entire function definition inside the class declaration

or

- Can place just the prototype inside the class declaration and write the function definition after the class

Defining Member Functions Inside the Class Declaration

- Member functions defined inside the class declaration are called inline functions
- Only very short functions, like the one below, should be inline functions

```
int getSide()
{ return side; }
```

Inline Member Function Example

```
class Square
{
  private:
    int side;
  public:
    void setSide(int s)
    { side = s; }
    int getSide()
    { return side; }
};
```

inline functions

Defining Member Functions After the Class Declaration

- Put a function prototype in the class declaration
- In the function definition, precede the function name with the class name and scope resolution operator (: :)

```
int Square::getSide()
{
  return side;
}
```

Conventions and a Suggestion

Conventions:

- Member variables are usually **`private`**
- Accessor and mutator functions are usually **`public`**
- Use 'get' in the name of accessor functions, 'set' in the name of mutator functions

Suggestion: calculate values to be returned in accessor functions when possible, to minimize the potential for stale data

Tradeoffs of Inline vs. Regular Member Functions

- When a regular function is called, control passes to the called function
  - the compiler stores return address of call, allocates memory for local variables, etc.
- Code for an inline function is copied into the program in place of the call when the program is compiled
  - This makes alarger executable program, but
  - There is less function call overhead, and possibly faster execution

Constructors

- A **constructor** is a member function that is often used to initialize data members of a class
- Is called automatically when an object of the class is created
- It must be a `public` member function
- It must be named the same as the class
- It must have no return type

Constructor – 2 Examples

Inline:	**Declaration outside the class:**

<pre>class Square
{
  . . .
  public:
    Square(int s)
    { side = s; }
  . . .
};</pre>
	<pre>Square(int);
	//prototype
	//in class
	
	Square::Square(int s)
	{
	   side = s;
	}</pre>

Overloading Constructors

- A class can have more than 1 constructor
- Overloaded constructors in a class must have different parameter lists

```
Square();
Square(int);
```

The Default Constructor

- Constructors can have any number of parameters, including none
- A **default constructor** is one that takes no arguments either due to
  - No parameters or
  - All parameters have default values
- If a class has any programmer-defined constructors, it must have a programmer- defined default constructor

Default Constructor Example

```
class Square
{
  private:
    int side;

  public:
    Square()        // default
    { side = 1; }   // constructor

    // Other member
    // functions go here
};
```

Has no parameters

Another Default Constructor Example

```
class Square
{
  private:
    int side;

  public:
    Square(int s = 1) // default
    { side = s; }     // constructor

    // Other member
    // functions go here
};
```

Has parameter but it has a default value

Invoking a Constructor

- To create an object using the default constructor, use no argument list and no **()**

```
Square square1;
```

- To create an object using a constructor that has parameters, include an argument list

```
Square square1(8);
```

Destructors

- Is a public member function automatically called when an object is destroyed
- The destructor name is **~***className*, *e.g.*, `~Square`
- It has no return type
- It takes no arguments
- Only 1 destructor is allowed per class
  (*i.e.*, it cannot be overloaded)

Private Member Functions

- A **`private`** member function can only be called by another member function of the same class
- It is used for internal processing by the class, not for use outside of the class

Passing Objects to Functions

- A class object can be passed as an argument to a function
- When passed by value, function makes a local copy of object. Original object in calling environment is unaffected by actions in function
- When passed by reference, function can use ‘set’ functions to modify the object.

Notes on Passing Objects

- Using a value parameter for an object can slow down a program and waste space

- Using a reference parameter speeds up program, but allows the function to modify data in the parameter

Notes on Passing Objects

- To save space and time, while protecting parameter data that should not be changed, use a **`const`** reference parameter

```
void showData(const Square &s)
                              // header
```

- In order to for the showData function to call **`Square`** member functions, those functions must use **`const`** in their prototype and header:

```
int Square::getSide() const;
```

Returning an Object from a Function

- A function can return an object

```
Square initSquare();    // prototype
s1 = initSquare();      // call
```

- The function must define a object
  - for internal use
  - to use with **return** statement

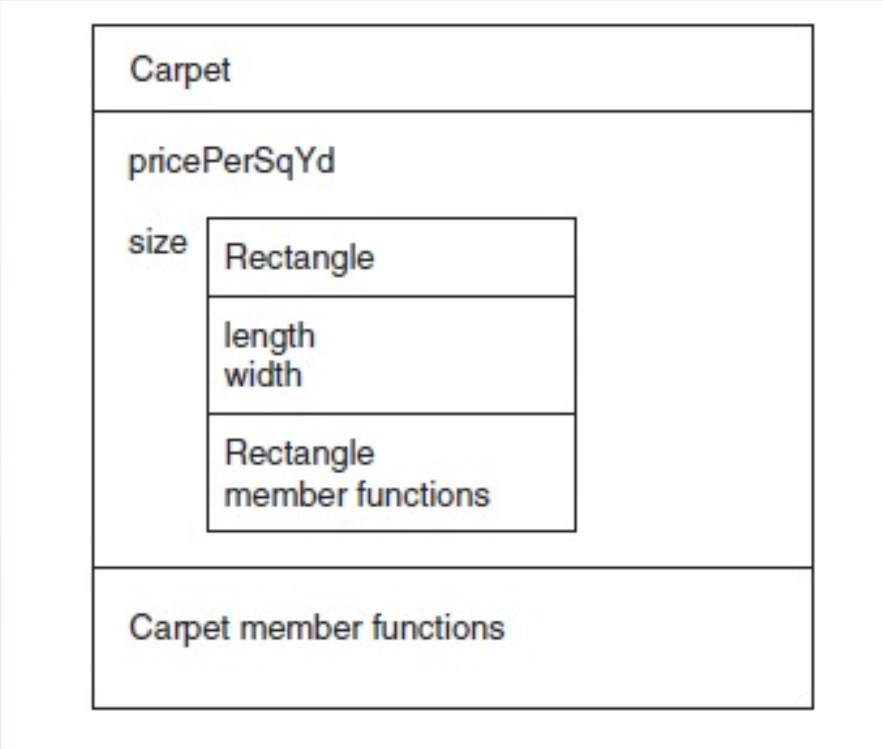
Returning an Object Example

```
Square initSquare()
{
  Square s;     // local variable
  int inputSize;
  cout << "Enter the length of side: ";
  cin >> inputSize;
  s.setSide(inputSize);
  return s;
}
```

Object Composition

- Occurs when an object is a member variable of another object.
- It is often used to design complex objects whose members are simpler objects
- ex. (from book): Define a rectangle class. Then, define a carpet class and use a rectangle object as a member of a carpet object.

Object Composition, cont.



Separating Class Specification, Implementation, and Client Code

Separating class declaration, member function definitions, and the program that uses the class into separate files is considered good design

Using Separate Files

- Place class declaration in a header file that serves as the class specification file. Name the file ***classname*.h** (for example, **Square.h**)
- Place member function definitions in a class implementation file. Name the file ***classname*.cpp** (for example, **Square.cpp**) This file should **#include** the class specification file.
- A client program (client code) that uses the class must **#include** the class specification file and be compiled and linked with the class implementation file.

Include Guards

- Used to prevent a header file from being included twice
- Format:

```
#ifndef symbol_name
#define symbol_name
. . .    (normal contents of header file)
#endif
```

- ***symbol_name*** is usually the name of the header file, in all capital letters:

```
#ifndef SQUARE_H
#define SQUARE_H
. . .
#endif
```

What Should Be Done Inside *vs.* Outside the Class

- Class should be designed to provide functions to store and retrieve data
- In general, input and output (I/O) should be done by functions that use class objects, rather than by class member functions

Structures

- Structure: Programmer-defined data type that allows multiple variables to be grouped together
- Structure Declaration Format:

```
struct structure name
{
 type1 field1;
 type2 field2;
   …
 typen fieldn;
};
```

Example `struct` Declaration

```
struct Student
{
   int studentID;
   string name;
  short year;
  double gpa;
};
```

structure name

structure members

Notice the required ;

`struct` Declaration Notes

- **`struct`** names commonly begin with an uppercase letter
- The structure name is also called the tag
- Multiple fields of same type can be in a comma-separated list

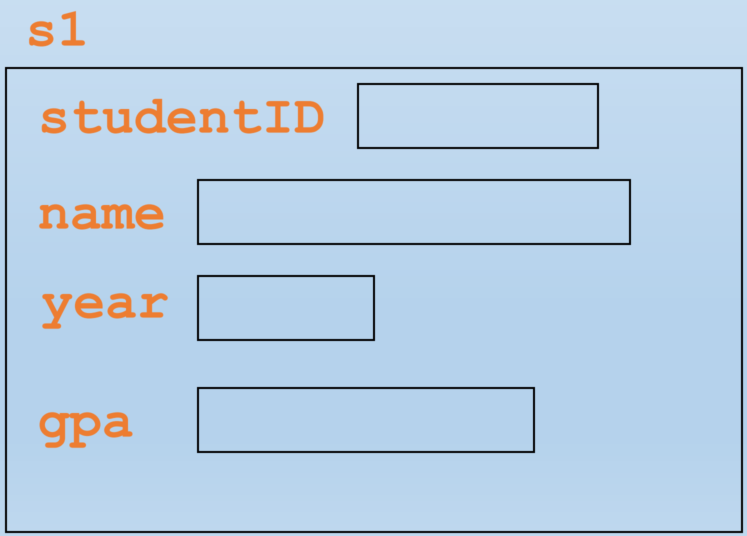
```
string name,
       address;
```

- Fields in a structure are all public by default

Defining Structure Variables

- **`struct`** declaration does not allocate memory or create variables
- To define variables, use structure tag as type name

```
Student s1;
```



Accessing Structure Members

- Use the dot **`(.)`** operator to refer to members of **`struct`** variables

```
getline(cin, s1.name);
cin >> s1.studentID;
s1.gpa = 3.75;
```

- Member variables can be used in any manner appropriate for their data type

Displaying **`struct`** Members

To display the contents of a **`struct`** variable, you must display each field separately, using the dot operator

Wrong:

```
cout << s1; // won't work!
```

Correct:

```
cout << s1.studentID << endl;
cout << s1.name << endl;
cout << s1.year << endl;
cout << s1.gpa;
```

Comparing **`struct`** Members

- Similar to displaying a **`struct`**, you cannot compare two **`struct`** variables directly:

```
if (s1 >= s2) // won't work!
```

- Instead, compare member variables:

```
if (s1.gpa >= s2.gpa) // better
```

Initializing a Structure

Cannot initialize members in the structure declaration, because no memory has been allocated yet

```
struct Student          // Illegal
{                       // initialization
  int studentID = 1145;
  string name = "Alex";
  short year = 1;
  float gpa = 2.95;
};
```

Initializing a Structure (continued)

- Structure members are initialized at the time a structure variable is created
- Can initialize a structure variable's members with either
  - an initialization list
  - a constructor

Using an Initialization List

An initialization list is an ordered set of values, separated by commas and contained in **{ }**, that provides initial values for a set of data members

```
{12, 6, 3}  // initialization list
            // with 3 values
```

More on Initialization Lists

- Order of list elements matters: First value initializes first data member, second value initializes second data member, etc.
- Elements of an initialization list can be constants, variables, or expressions

```
{12, W, L/W + 1} // initialization list
                 // with 3 items
```

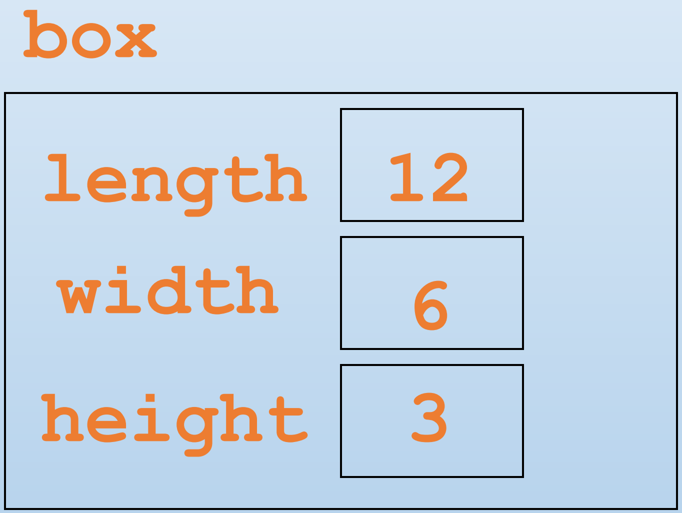
Initialization List Example

Structure Declaration

```
struct Dimensions
{ int length,
      width,
      height;
};

Dimensions box = {12,6,3};
```

Structure Variable



Partial Initialization

Can initialize just some members, but cannot skip over members

```
Dimensions box1 = {12,6};  //OK
Dimensions box2 = {12,,3}; //illegal
```

Problems with Initialization List

- Can't omit a value for a member without omitting values for all following members
- Does not work on most modern compilers if the structure contains any string objects
  - Will, however, work with C-string members

Using a Constructor to Initialize Structure Members

- Similar to a constructor for a class:
  - name is the same as the name of the struct
  - no return type
  - used to initialize data members
- It is normally written inside the **`struct`** declaration

A Structure with a Constructor

```
struct Dimensions
{
   int length,
       width,
       height;
   // Constructor
   Dimensions(int L, int W, int H)
   {length = L; width = W; height = H;}
};
```

Nested Structures

A structure can have another structure as a member.

```
struct PersonInfo
{   string name,
           address,
           city;
};
struct Student
{   int          studentID;
    PersonInfo   pData;
    short        year;
    double       gpa;
};
```

Members of Nested Structures

Use the dot operator multiple times to access fields of nested structures

```
Student s5;
s5.pData.name = "Joanne";
s5.pData.city = "Tulsa";
```

Structures as Function Arguments

- May pass members of **`struct`** variables to functions

```
computeGPA(s1.gpa);
```

- May pass entire **`struct`** variables to functions

```
showData(s5);
```

- Can use reference parameter if function needs to modify contents of structure variable

Notes on Passing Structures

- Using a value parameter for structure can slow down a program and waste space
- Using a reference parameter speeds up program, but allows the function to modify data in the structure
- To save space and time, while protecting structure data that should not be changed, use a **`const`** reference parameter

```
void showData(const Student &s)
                                // header
```

Returning a Structure from a Function

- Function can return a **`struct`**

```
Student getStuData();  // prototype
s1 = getStuData();     // call
```

- Function must define a local structure variable
  - for internal use
  - to use with **`return`** statement

Returning a Structure Example

```
Student getStuData()
{ Student s;     // local variable
  cin >> s.studentID;
  cin.ignore();
  getline(cin, s.pData.name);
  getline(cin, s.pData.address);
  getline(cin, s.pData.city);
  cin >> s.year;
  cin >> s.gpa;
  return s;
}
```

Unions

- Similar to a **`struct`**, but
  - all members share a single memory location, which saves space
  - only 1 member of the union can be used at a time
- Declared using key word **`union`**
- Otherwise the same as **`struct`**
- Variables defined and accessed like **`struct`** variables

Example `union` Declaration

```
union WageInfo
{
   double hourlyRate;
   float annualSalary;
};
```

union tag

union members

Notice the required ;

Introduction to Object-Oriented Analysis and Design

- Object-Oriented Analysis: that phase of program development when the program functionality is determined from the requirements

- It includes
  - identification of objects and classes
  - definition of each class's attributes
  - identification of each class's behaviors
  - definition of the relationship between classes

Identify Objects and Classes

- Consider the major data elements and the operations on these elements
- Candidates include
  - user-interface components (menus, text boxes, *etc.*)
  - I/O devices
  - physical objects
  - historical data (employee records, transaction logs, *etc.*)
  - the roles of human participants

Define Class Attributes

- Attributes are the data elements of an object of the class
- They are necessary for the object to work in its role in the program

Define Class Behaviors

- For each class,
  - Identify what an object of a class should do in the program
- The behaviors determine some of the member functions of the class

Relationships Between Classes

Possible relationships

- Access ("uses-a")
- Ownership/Composition ("has-a")
- Inheritance ("is-a")

Finding the Classes

Technique:

- Write a description of the problem domain (objects, events, etc. related to the problem)
- List the nouns, noun phrases, and pronouns. These are all candidate objects
- Refine the list to include only those objects that are relevant to the problem

Determine Class Responsibilities

Class responsibilities:

- What is the class responsible to know?
- What is the class responsible to do?

Use these to define some of the member functions

Object Reuse

- A well-defined class can be used to create objects in multiple programs
- By re-using an object definition, program development time is shortened
- One goal of object-oriented programming is to support object reuse