Chapter 7:
Introduction to Classes and Objects

Starting Out with C++
Early Objects
Global Edition

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Topics

Topics (Continued)

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7.1 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 in the book:
  - 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(不等邊), isosceles(等腰), or equilateral(正)

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

7.2 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.

7.3 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 **`(Book P447, ePP413)`**
- Can appear multiple times in a class
- If not specified, the default is **`private`**

7.4 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();
```

(P449 Program 7-1, eP415)

Types of Member Functions

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

  ex: `getSide`

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

  ex: `setSide`

7.5 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;
}
```

(P452 Program 7-2, eP418)

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

(P453 Program 7-3, eP419)

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 a larger executable program, but
  - There is less function call overhead, and possibly faster execution

7.6 Constructors

- A **constructor** is a member function that is often used to initialize data members of a class (P459 Program 7-5, eP425)
- Is called automatically when an object of the class is created (P458 Program 7-4, eP424)
- 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:

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

Overloading Constructors

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

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

(P461 Program 7-6, eP427)

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);
```

7.7 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) (P463 Program 7-7, eP429)

7. 8 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
- (P466 Program 7-8, eP432)

7.9 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.
- (P470 Program 7-9, eP436)

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 an object
  – for internal use
  – to use with **`return`** statement

Returning an Object Example

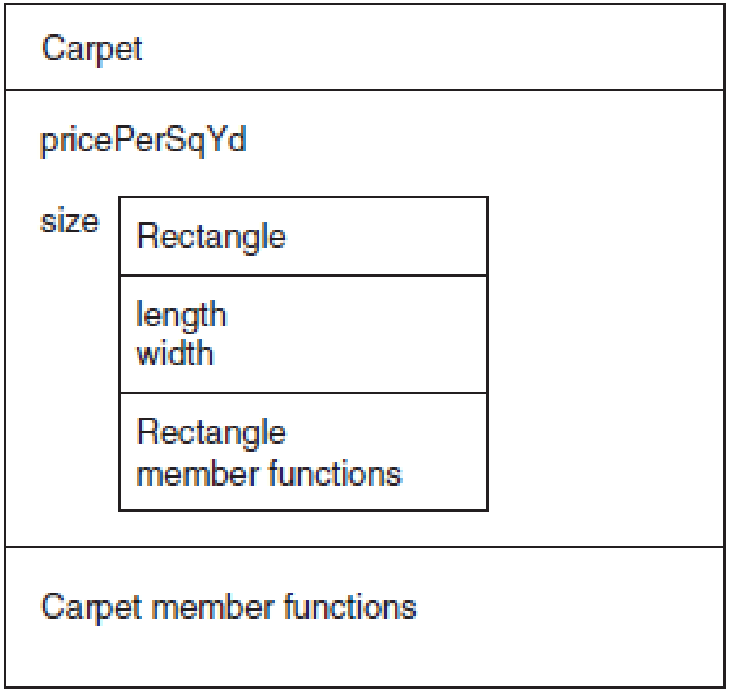
```
Square initSquare()
{
  Square s;     // local variable
  int inputSize;
  cout << "Enter the length of side: ";
  cin >> inputSize;
  s.setSide(inputSize);
  return s;
}
```

(P473 Program 7-10, eP439)

7.10 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.



(P477 Program 7-11, eP443)

7.11 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
```

Example

- P481 Rectangle.h (eP447)
- P482 Rectangle.cpp (eP448)
- P484 pr7-12.cpp (client code,eP450)
- P485 Table 7-1 + Figure 7-5
- Project (eP451)

Advantage of Using Multiple Files

- Abstraction
- Just provide a copy of the specification file and the compiled object file for the class implementation
- Easy to handle when the class member functions must be modified

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

7.12 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

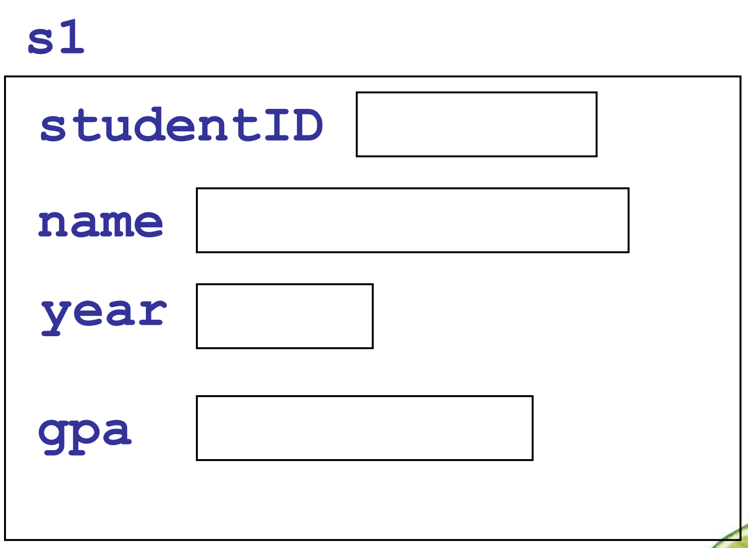
```
string name,
       address;
```

- 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;
};
```

Structure Variable

box

length	12
width	6
height	3

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

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=0, int W=0, int H=0)
   {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";
```

(P493 Program 7-14, eP459)

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;
}
```

7.13 More About Enumerated Data Types

Additional ways that enumerated data types can be used:

- Data type declaration and variable definition in a single statement:

```
enum Tree {ASH, ELM, OAK} tree1, tree2;
```

- Assign an int value to an enum variable:

```
enum Tree {ASH, ELM, OAK} tree1;
tree1 = static_cast<Tree>(1);  // ELM
```

More About Enumerated Data Types

- Assign the value of an enum variable to an int:

```
enum Tree {ASH, ELM, OAK} tree1;
tree1 = ELM;
int thisTree = tree1;  // assigns 1
int thatTree = OAK;    // assigns 2
```

More About Enumerated Data Types

- Assign the result of a computation to an enum variable

```
enum Tree {ASH, ELM, OAK} tree1, tree2;
tree1 = ELM;
tree2 = static_cast<Tree>(tree1 + 1);
                         // assigns OAK
```

More About Enumerated Data Types

- Using enumerators in a switch statement

```
enum Tree {ASH, ELM, OAK} tree1;
switch(tree1)
{
 case ASH: cout << "Ash";
           break;
 case ELM: cout << "Elm";
           break;
 case OAK: cout << "Oak";
           break;
}
```

More About Enumerated Data Types

- Using enumerators for loop control:

```
enum Tree {ASH, ELM, OAK};
for (Tree tree1 = ASH; tree1 <= OAK;
      tree1=static_cast<Tree>(tree1+1))
{
  .
  .
  .
}
```

Strongly Typed enums (C++ 11)

- Enumerated values (names) cannot be re-used in different enumerated data types that are in the same scope.
- A strongly typed enum (an enum class) allows you to do this

```
enum class Tree {ASH, ELM, OAK};
enum class Street {RUSH, OAK, STATE};
```

- Note the keyword **`class`** in the declaration

More on Strongly Typed enums (C++ 11)

- Because enumerators can be used in multiple enumerated data types, references must include the name of the strongly typed enum followed by : :

```
enum class Tree : char {ASH, ELM, OAK};
Tree tree1 = Tree::OAK;
```

More on Strongly Typed enums (C++ 11)

- Strongly typed enumerators are stored as ints by default.
- To choose a different integer data type, indicate the type after the enum name and before the enumerator list:

```
enum class Tree : char {ASH, ELM, OAK};
```

More on Strongly Typed enums (C++ 11)

- To retrieve the integer value associated with a strongly-typed enumerator, cast it to an int:

```
enum class Tree : char {ASH, ELM, OAK};
int val = static_cast<int>(Trees::ASH);
```

Example

```
// This program uses two strongly typed enumerated data types.
#include <iostream>
using namespace std;

enum class Presidents { MCKINLEY, ROOSEVELT, TAFT };
enum class VicePresidents { ROOSEVELT, FAIRBANKS, SHERMAN };

int main()
{
        Presidents prez = Presidents::ROOSEVELT;
        VicePresidents vp1 = VicePresidents::ROOSEVELT;
        VicePresidents vp2 = VicePresidents::SHERMAN;

        cout << static_cast<int>(prez) << "  " << static_cast<int>(vp1)
            << "  " << static_cast<int>(vp2) << endl;
        return 0;
}
```

7.14 Home Software Company OOP Case Study

P 503 Case study eP467

7.15 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 (vehicles, machines,…)
  - 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 (ex: menuItem, CustomerOrder,…)

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 (P513~519, eP477)

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

Object-Oriented vs. Object-Based Programming

- Using classes and objects might more correctly be referred to as object-based programming. When we add the ability to define relationships among different classes of objects, to create classes of objects from other classes (inheritance) and to determine the behavior of a member function depending on which object calls it (polymorphism), it becomes true object-oriented programming.

Homework 3 (1/2)

TEXT BOOK CH. 7

Programming Challenges 19. Patient Fees (P.539, eP.502)

Group Project (1、2或4人)（禁止3人）

要求：

作業總共四個部分，需要平均分配工作量，

並請在你負責的部份註解上你的學號姓名，

最後必須要在有 **main**的檔案開頭

註解小組成員的 學號、姓名、負責部份、開發中遇到的問題＆解決方案（最少兩個，獨立開發則不用）

Homework 3 (2/2)

19. Patient Fees

This program should be designed and written by a team of students. Here are some suggestions:

- One or more students may work on a single class.
- The requirements of the program should be analyzed so each student is given about the same workload.
- The names, parameters, and return types of each function and class member function should be decided in advance.
- The program will be best implemented as a multifile program.

Write a program that computes a patient's bill for a hospital stay. The different components of the program are

- The `PatientAccount` class will keep a total of the patient's charges. It will also keep track of the number of days spent in the hospital. The group must decide on the hospital's daily rate.
- The `Surgery` class will have stored within it the charges for at least five types of surgery. It can update the `charges` variable of the `PatientAccount` class.
- The `Pharmacy` class will have stored within it the price of at least five types of medication. It can update the `charges` variable of the `PatientAccount` class.
- The `main` program.

The student who designs the main program will design a menu that allows the user to enter a type of surgery, enter one or more types of medication, and check the patient out of the hospital. When the patient checks out, the total charges should be displayed.

Homework 4

TEXT BOOK CH. 7 (P.513, eP.477)

課本513頁(電子書477頁)有一段對於Joe's Automotive Shop的需求描述，以此為基礎再加上manager可隨時刪除、查詢估價單(service quote)，查詢時可以"客戶名字"或"估價單日期"作為關鍵字，列出所有符合關鍵字的估價單。

請依上述需求，實作一object-based program，並製作使用說明文件，說明如何使用你的程式，若有特殊功能亦請詳述。