

3

Introduction to Classes and Objects



You will see something new. Two things. And I call them Thing One and Thing Two.

— Dr. Theodor Seuss Geisel

Nothing can have value without being an object of utility.

— Karl Marx

Your public servants serve you right.

— Adlai E. Stevenson

Knowing how to answer one who speaks, To reply to one who sends a message.

— Amenemope

OBJECTIVES

- In this chapter you will learn:
- What classes, objects, member functions and data members are.
- How to define a class and use it to create an object.
- How to define member functions in a class to implement the class's behaviors.
- How to declare data members in a class to implement the class's attributes.
- How to call a member function of an object to make that member function perform its task.
- The differences between data members of a class and local variables of a function.
- How to use a constructor to ensure that an object's data is initialized when the object is created.
- How to engineer a class to separate its interface from its implementation and encourage reuse.



- 3.1 Introduction
- 3.2 Classes, Objects, Member Functions and Data Members
- 3.3 Overview of the Chapter Examples
- 3.4 Defining a Class with a Member Function
- 3.5 Defining a Member Function with a Parameter
- 3.6 Data Members, *set* Functions and *get* Functions
- 3.7 Initializing Objects with Constructors
- 3.8 Placing a Class in a Separate File for Reusability
- 3.9 Separating Interface from Implementation
- 3.10 Validating Data with set Functions
- 3.11 (Optional) Software Engineering Case Study: Identifying the Classes in the ATM Requirements Document
- 3.12 Wrap-Up



3.1 Introduction

- **Programs from Chapter 2**
 - All statements were located in function main
- **Typically**
 - Programs will consist of
 - Function main and
 - One or more classes
 - Each containing data members and member functions



3.2 Classes, Objects, Member Functions and Data Members⁶

- **Review of classes: Car example**
 - **Functions describe the mechanisms that perform a tasks, such as acceleration**
 - **Hides complex tasks from user, just as a driver can use the pedal to accelerate without needing to know how the acceleration is performed**
 - **Classes must be defined before they can be used, car must be built before it can be driven**
 - **Many car objects created from same class, many cars built from same engineering drawing**



3.2 Classes, Objects, Member Functions and Data Members (Cont.)⁷

- **Review of classes: Car example (Cont.)**
 - **Member-function calls send messages to an object to perform tasks, just like pressing the gas pedal sends a message to the car to accelerate**
 - **Objects and cars both have attributes, like color and miles driven**



3.3 Overview of the Chapter Examples

- **Seven simple examples**
 - **Examples used to build a GradeBook class**
- **Topics covered:**
 - **Member functions**
 - **Data members**
 - **Clients of a class**
 - **Other classes or functions that call the member functions of this class's objects**
 - **Separating interface from implementation**
 - **Data validation**
 - **Ensures that data in an object is in a particular format or range**



3.4 Defining a Class With a Member Function⁹

- **Class definition**

- Tells compiler what member functions and data members belong to the class
- Keyword **class** followed by the class's name
- Class body is enclosed in braces ({})
 - Specifies data members and member functions
 - Access-specifier **public**:
 - Indicates that a member function or data member is accessible to other functions and member functions of other classes



```
1 // Fig. 3.1: fig03_01.cpp
2 // Define class GradeBook with a member function displayMessage;
3 // Create a GradeBook object and call its displayMessage function.
```

```
4 #include <iostream>
```

```
5 using std::cout;
```

```
6 using std::endl;
```

```
7
```

```
8 // GradeBook class definition
```

```
9 class GradeBook
```

```
10 {
```

```
11 public:
```

```
12 // function that displays a welcome message to the user
```

```
13 void displayMessage()
```

```
14 {
```

```
15     cout << "Welcome to the Grade Book!" << endl;
```

```
16 } // end function displayMessage
```

```
17 }; // end class GradeBook
```

```
18
```

```
19 // function main begins program execution
```

```
20 int main()
```

```
21 {
```

```
22     GradeBook myGradeBook; // create a GradeBook object named myGradeBook
```

```
23     myGradeBook.displayMessage(); // call object's displayMessage function
```

```
24     return 0; // indicate successful termination
```

```
25 } // end main
```

Beginning of class definition
for class **GradeBook**

Beginning of class body

Access specifier **public**; makes
members available

Member function **displayMessage**
returns nothing

End of class body

Use dot operator to call
GradeBook's member function

Welcome to the Grade Book!



Common Programming Error 3.1

Forgetting the semicolon at the end of a class definition is a syntax error.



3.4 Defining a Class With a Member Function (Cont.)¹²

- **Member function definition**
 - **Return type of a function**
 - Indicates the type of value returned by the function when it completes its task
 - **void** indicates that the function does not return any value
 - **Function names must be a valid identifier**
 - **Parentheses after function name indicate that it is a function**
 - **Function body contains statements that perform the function's task**
 - **Delimited by braces ({})**



Common Programming Error 3.2

Returning a value from a function whose return type has been declared void is a compilation error.



Common Programming Error 3.3

Defining a function inside another function is a syntax error.



3.4 Defining a Class With a Member Function (Cont.)

- **Using a class**
 - **A class is a user-defined type (or programmer-defined type)**
 - **Can be used to create objects**
 - **Variables of the class type**
 - **C++ is an extensible language**
 - **Dot operator (.)**
 - **Used to access an object's data members and member functions**
 - **Example**
 - **myGradeBook.displayMessage()**
 - **Call member function displayMessage of GradeBook object myGradeBook**





Fig.3.2 | UML class diagram indicating that class **GradeBook has a public **displayMessage** operation.**

3.4 Defining a Class With a Member Function (Cont.)¹⁷

- **UML class diagram**
 - **A rectangle with three compartments**
 - **Top compartment contains the name of the class**
 - **Middle compartment contains the class's attributes**
 - **Bottom compartment contains the class's operations**
 - **A (+) in front of an operation indicates it is public**

3.5 Defining a Member Function with a Parameter¹⁸

- **Function parameter(s)**
 - Information needed by a function to perform its task
- **Function argument(s)**
 - Values supplied by a function call for each of the function's parameters
 - Argument values are copied into function parameters

3.5 Defining a Member Function with a Parameter (Cont.)

- **A string**
 - Represents a string of characters
 - An object of C++ Standard Library class `std::string`
 - Defined in header file `<string>`
- **Library function `getline`**
 - Used to retrieve input until newline is encountered
 - Example
 - `getline(cin, nameOfCourse);`
 - Inputs a line from standard input into string object `nameOfCourse`

```
1 // Fig. 3.3: fig03_03.cpp
2 // Define class GradeBook with a member function that takes a parameter;
3 // Create a GradeBook object and call its displayMessage function.
4 #include <iostream>
5 using std::cout;
6 using std::cin;
7 using std::endl;
8
9 #include <string> // program uses C++ standard string class
10 using std::string;
11 using std::getline;
12
13 // GradeBook class definition
14 class GradeBook
15 {
16 public:
17     // function that displays a welcome message to the GradeBook user
18     void displayMessage( string courseName )
19     {
20         cout << "Welcome to the grade book for\n" << courseName << "!"
21             << endl;
22     } // end function displayMessage
23 }; // end class GradeBook
24
25 // function main begins program execution
26 int main()
27 {
28     string nameOfCourse; // string of characters to store the course name
29     GradeBook myGradeBook; // create a GradeBook object named myGradeBook
30 }
```

Include string class definition

Member function parameter

Use the function
parameter as a variable



```
31 // prompt for and input course name
32 cout << "Please enter the course name: " << endl;
33 getline( cin, nameOfCourse ); // read a course name with blanks
34 cout << endl; // output a blank line
35
36 // call myGradeBook's displayMessage function
37 // and pass nameOfCourse as an argument
38 myGradeBook.displayMessage( nameOfCourse );
39 return 0; // indicate successful termination
40 } // end main
```

Passing an argument to
the member function

Please enter the course name:
CS101 Introduction to C++ Programming

Welcome to the grade book for
CS101 Introduction to C++ Programming!



3.5 Defining a Member Function with a Parameter (Cont.)

- **Parameter Lists**

- Additional information needed by a function
- Located in parentheses following the function name
- Function may have any number of parameters
 - Parameters separated by commas
- Number, order and types of arguments in a function call must match the number, order and types of parameters in the called function's parameter list
- Modeled in UML
 - Parameter name, followed by a colon and the parameter type in the member function's parentheses



Common Programming Error 3.4

Placing a semicolon after the right parenthesis enclosing the parameter list of a function definition is a syntax error.

Common Programming Error 3.5

Defining a function parameter again as a local variable in the function is a compilation error.



Good Programming Practice 3.1

To avoid ambiguity, do not use the same names for the arguments passed to a function and the corresponding parameters in the function definition.

Good Programming Practice 3.2

Choosing meaningful function names and meaningful parameter names makes programs more readable and helps avoid excessive use of comments.



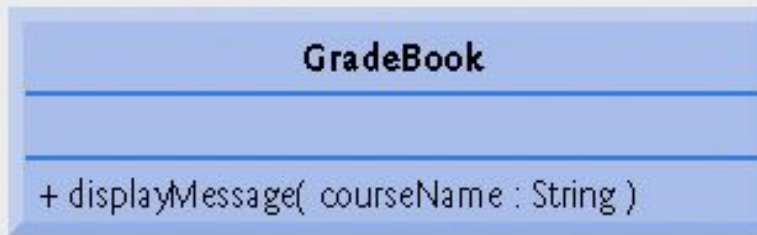


Fig.3.4 | UML class diagram indicating that class `GradeBook` has a `displayMessage` operation with a `courseName` parameter of UML type `String`.

3.6 Data Members, *set* Functions and *get* Functions

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- **Local variables**

- Variables declared in a function definition's body
 - Cannot be used outside of that function body
- When a function terminates
 - The values of its local variables are lost

- **Attributes**

- Exist throughout the life of the object
- Represented as data members
 - Variables in a class definition
- Each object of class maintains its own copy of attributes



```
1 // Fig. 3.5: fig03_05.cpp
2 // Define class GradeBook that contains a courseName data member
3 // and member functions to set and get its value;
4 // Create and manipulate a GradeBook object with these functions.
5 #include <iostream>
6 using std::cout;
7 using std::cin;
8 using std::endl;
9
10 #include <string> // program uses C++ standard string class
11 using std::string;
12 using std::getline;
13
14 // GradeBook class definition
15 class GradeBook
16 {
17 public:
18     // function that sets the course name
19     void setCourseName( string name )
20     {
21         courseName = name; // store the course name in the object
22     } // end function setCourseName
23
24     // function that gets the course name
25     string getCourseName()
26     {
27         return courseName; // return the object's courseName
28     } // end function getCourseName
29
```

set function modifies **private** data

get function accesses **private** data



```
30 // function that displays a welcome message
31 void displayMessage()
32 {
33     // this statement calls getCourseName to get the
34     // name of the course this GradeBook represents
35     cout << "Welcome to the grade book for\n" << getCourseName() << "!"
36         << endl;
37 } // end function displayMessage
38 private:
39     string courseName; // course name for this GradeBook
40 }; // end class GradeBook
41
42 // function main
43 int main()
44 {
45     string nameOfCourse; // string of characters to store the course name
46     GradeBook myGradeBook; // create a GradeBook object named myGradeBook
47
48     // display initial value of courseName
49     cout << "Initial course name is: " << myGradeBook.getCourseName()
50         << endl;
51
```

Use *set* and *get* functions,
even within the class

private members accessible only
to member functions of the class

Accessing **private** data outside class definition



```
52 // prompt for, input and set course name
53 cout << "\nPlease enter the course name:" << endl;
54 getline( cin, nameOfCourse ); // read a course name with blanks
55 myGradeBook.setCourseName( nameOfCourse ); // set the course name
56
57 cout << endl; // outputs a blank line
58 myGradeBook.displayMessage(); // display message with new course name
59 return 0; // indicate success
60 } // end main
```

Modifying **private** data outside class definition (2 of 3)

Initial course name is:

Please enter the course name:
CS101 Introduction to C++ Programming

Welcome to the grade book for
CS101 Introduction to C++ Programming!



Good Programming Practice 3.3

Place a blank line between member-function definitions to enhance program readability.



3.6 Data Members, *set* Functions and *get* Functions (Cont.)

- **Access-specifier private**
 - Makes a data member or member function accessible only to member functions of the class
 - private is the default access for class members
 - Data hiding
- **Returning a value from a function**
 - A function that specifies a return type other than void
 - Returns a value to its calling function



Software Engineering Observation 3.1

As a rule of thumb, data members should be declared private and member functions should be declared public. (We will see that it is appropriate to declare certain member functions private, if they are to be accessed only by other member functions of the class.)



Common Programming Error 3.6

An attempt by a function, which is not a member of a particular class (or a friend of that class, as we will see in Chapter 10), to access a private member of that class is a compilation error.



Good Programming Practice 3.4

Despite the fact that the public and private access specifiers may be repeated and intermixed, list all the public members of a class first in one group and then list all the private members in another group. This focuses the client's attention on the class's public interface, rather than on the class's implementation.



Good Programming Practice 3.5

If you choose to list the private members first in a class definition, explicitly use the private access specifier despite the fact that private is assumed by default. This improves program clarity.



Software Engineering Observation 3.2

We will learn in Chapter 10, Classes: Part 2, that functions and classes declared by a class to be friends can access the private members of the class.



Error-Prevention Tip 3.1

Making the data members of a class private and the member functions of the class public facilitates debugging because problems with data manipulations are localized to either the class's member functions or the friends of the class.



Common Programming Error 3.7

Forgetting to return a value from a function that is supposed to return a value is a compilation error.



3.6 Data Members, *set* Functions and *get* Functions (Cont.)

- **Software engineering with *set* and *get* functions**
 - public member functions that allow clients of a class to set or get the values of private data members
 - *set* functions sometimes called mutators and *get* functions sometimes called accessors
 - Allows the creator of the class to control how clients access private data
 - Should also be used by other member functions of the same class



Good Programming Practice 3.6

Always try to localize the effects of changes to a class's data members by accessing and manipulating the data members through their get and set functions. Changes to the name of a data member or the data type used to store a data member then affect only the corresponding get and set functions, but not the callers of those functions.



Software Engineering Observation 3.3

It is important to write programs that are understandable and easy to maintain. Change is the rule rather than the exception. Programmers should anticipate that their code will be modified.



Software Engineering Observation 3.4

The class designer need not provide set or get functions for each private data item; these capabilities should be provided only when appropriate. If a service is useful to the client code, that service should typically be provided in the class's public interface.



3.6 Data Members, *set* Functions and *get* Functions (Cont.)

- **UML diagram**

- **Indicating the return type of an operation**
 - **Place a colon and the return type after the parentheses following the operation name**
- **Minus sign used to indicate private members**



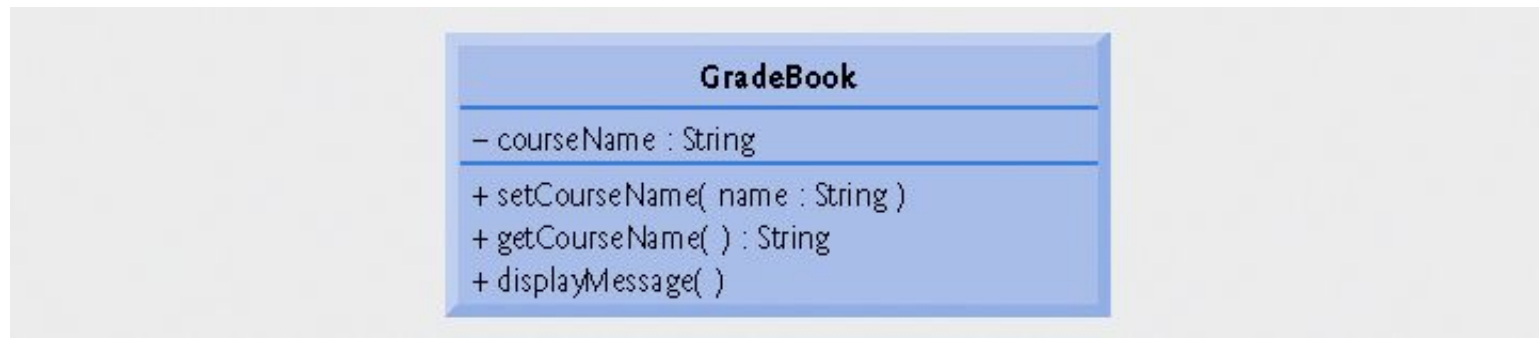


Fig.3.6 | UML class diagram for class GradeBook with a private courseName attribute and public operations setCourseName, getCourseName and displayMessage.

3.7 Initializing Objects with Constructors

- **Constructors**

- **Functions used to initialize an object's data when it is created**
 - **Call made implicitly when object is created**
 - **Must be defined with the same name as the class**
 - **Cannot return values**
 - **Not even void**
- **Default constructor has no parameters**
 - **The compiler will provide one when a class does not explicitly include a constructor**
 - **Compiler's default constructor only calls constructors of data members that are objects of classes**



```
1 // Fig. 3.7: fig03_07.cpp
2 // Instantiating multiple objects of the GradeBook class and using
3 // the GradeBook constructor to specify the course name
4 // when each GradeBook object is created.
5 #include <iostream>
6 using std::cout;
7 using std::endl;
8
9 #include <string> // program uses C++ standard string class
10 using std::string;
11
12 // GradeBook class definition
13 class GradeBook
14 {
15 public:
16     // constructor initializes courseName with string supplied as argument
17     GradeBook( string name )
18     {
19         setCourseName( name ); // call set function to initialize courseName
20     } // end GradeBook constructor
21
22     // function to set the course name
23     void setCourseName( string name )
24     {
25         courseName = name; // store the course name in the object
26     } // end function setCourseName
27
```

Constructor has same name as
class and no return type

Initialize data member



fig03_07.cpp

(2 of 3)

```
28 // function to get the course name
29 string getCourseName()
30 {
31     return courseName; // return object's courseName
32 } // end function getCourseName
33
34 // display a welcome message to the GradeBook user
35 void displayMessage()
36 {
37     // call getCourseName to get the courseName
38     cout << "Welcome to the grade book for\n" << getCourseName()
39         << "!" << endl ;
40 } // end function displayMessage
41 private:
42     string courseName; // course name for this GradeBook
43 }; // end class GradeBook
44
```



```
45 // function main begins program execution
46 int main()
47 {
48     // create two GradeBook objects
49     GradeBook gradeBook1( "CS101 Introduction to C++ Programming" );
50     GradeBook gradeBook2( "CS102 Data Structures in C++" );
51
52     // display initial value of courseName for each GradeBook
53     cout << "gradeBook1 created for course: " << gradeBook1.getCourseName()
54         << "\ngradeBook2 created for course: " << gradeBook2.getCourseName()
55         << endl ;
56     return 0; // indicate successful termination
57 } // end main
```

Creating objects implicitly calls the constructor

```
gradeBook1 created for course: CS101 Introduction to C++ Programming
gradeBook2 created for course: CS102 Data Structures in C++
```



Error-Prevention Tip 3.2

Unless no initialization of your class's data members is necessary (almost never), provide a constructor to ensure that your class's data members are initialized with meaningful values when each new object of your class is created.



Software Engineering Observation 3.5

Data members can be initialized in a constructor of the class or their values may be set later after the object is created. However, it is a good software engineering practice to ensure that an object is fully initialized before the client code invokes the object's member functions. In general, you should not rely on the client code to ensure that an object gets initialized properly.



3.7 Initializing Objects with Constructors (Cont.)

- **Constructors in a UML class diagram**
 - Appear in third compartment, with operations
 - To distinguish a constructor from a class's operations
 - UML places the word “constructor” between guillemets before the constructor's name
 - `<<constructor>>`
 - Usually placed before other operations

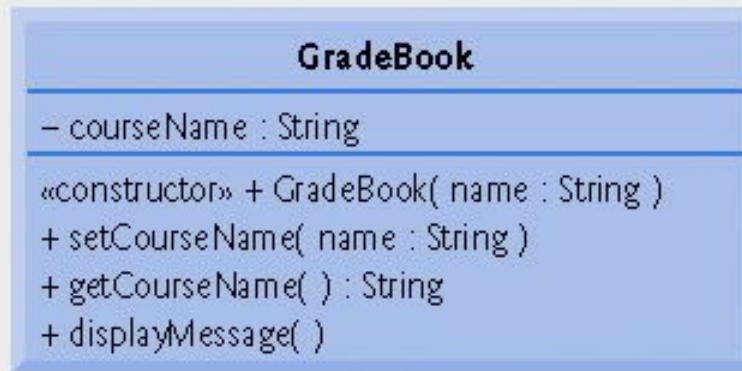


Fig.3.8 | UML class diagram indicating that class GradeBook has a constructor with a name parameter of UML type String.

3.8 Placing a Class in a Separate File for Reusability⁵⁵

- **.cpp file is known as a source-code file**
- **Header files**
 - **Separate files in which class definitions are placed**
 - **Allow compiler to recognize the classes when used elsewhere**
 - **Generally have .h filename extensions**
- **Driver files**
 - **Program used to test software (such as classes)**
 - **Contains a main function so it can be executed**



fig03_09.cpp

(1 of 2)

```
1 // Fig. 3.9: GradeBook.h
2 // GradeBook class definition in a separate file from main.
3 #include <iostream>
4 using std::cout;
5 using std::endl;
6
7 #include <string> // class GradeBook uses C++ standard string class
8 using std::string;
9
10 // GradeBook class definition
11 class GradeBook
12 {
13 public:
14     // constructor initializes courseName with string supplied as argument
15     GradeBook( string name )
16     {
17         setCourseName( name ); // call set function to initialize courseName
18     } // end GradeBook constructor
19
20     // function to set the course name
21     void setCourseName( string name )
22     {
23         courseName = name; // store the course name in the object
24     } // end function setCourseName
25
```

Class definition is in a header file



fig03_09.cpp

(2 of 2)

```
26 // function to get the course name
27 string getCourseName()
28 {
29     return courseName; // return object's courseName
30 } // end function getCourseName
31
32 // display a welcome message to the GradeBook user
33 void displayMessage()
34 {
35     // call getCourseName to get the courseName
36     cout << "Welcome to the grade book for\n" << getCourseName()
37         << "!" << endl;
38 } // end function displayMessage
39 private:
40     string courseName; // course name for this GradeBook
41 }; // end class GradeBook
```



fig03_10.cpp

(1 of 1)

```
1 // Fig. 3.10: fig03_10.cpp
2 // Including class GradeBook from file GradeBook.h for use in main.
3 #include <iostream>
4 using std::cout;
5 using std::endl;
6
7 #include "GradeBook.h" // include definition of class GradeBook
8
9 // function main begins program execution
10 int main()
11 {
12     // create two GradeBook objects
13     GradeBook gradeBook1( "CS101 Introduction to C++ Programming" );
14     GradeBook gradeBook2( "CS102 Data Structures in C++" );
15
16     // display initial value of courseName for each GradeBook
17     cout << "gradeBook1 created for course: " << gradeBook1.getCourseName()
18         << "\ngradeBook2 created for course: " << gradeBook2.getCourseName()
19         << endl;
20     return 0; // indicate successful termination
21 } // end main
```

Including the header file causes the class definition to be copied into the file

```
gradeBook1 created for course: CS101 Introduction to C++ Programming
gradeBook2 created for course: CS102 Data Structures in C++
```



3.8 Placing a Class in a Separate File for Reusability (Cont.)⁵⁹

- **#include preprocessor directive**
 - **Used to include header files**
 - **Instructs C++ preprocessor to replace directive with a copy of the contents of the specified file**
 - **Quotes indicate user-defined header files**
 - **Preprocessor first looks in current directory**
 - **If the file is not found, looks in C++ Standard Library directory**
 - **Angle brackets indicate C++ Standard Library**
 - **Preprocessor looks only in C++ Standard Library directory**



3.8 Placing a Class in a Separate File for Reusability (Cont.)

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- **Creating objects**
 - **Compiler must know size of object**
 - **C++ objects typically contain only data members**
 - **Compiler creates one copy of class's member functions**
 - **This copy is shared among all the class's objects**



Error-Prevention Tip 3.3

To ensure that the preprocessor can locate header files correctly, `#include` preprocessor directives should place the names of user-defined header files in quotes (e.g., "GradeBook.h") and place the names of C++ Standard Library header files in angle brackets (e.g., `<iostream>`).



3.9 Separating Interface from Implementation

- **Interface**

- **Describes what services a class's clients can use and how to request those services**
 - **But does not reveal how the class carries out the services**
 - **A class definition that lists only member function names, return types and parameter types**
 - **Function prototypes**
- **A class's interface consists of the class's public member functions (services)**

- **Separating interface from implementation**

- **Client code should not break if implementation changes, as long as interface stays the same**



3.9 Separating Interface from Implementation (Cont.)

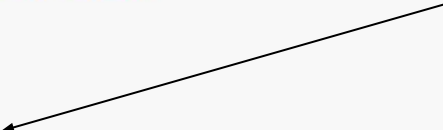
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- **Separating interface from implementation (Cont.)**
 - **Define member functions outside the class definition, in a separate source-code file**
 - **In source-code file for a class**
 - **Use binary scope resolution operator (::) to tie each member function to the class definition**
 - **Implementation details are hidden**
 - **Client code does not need to know the implementation**
 - **In header file for a class**
 - **Function prototypes describe the class's public interface**



```
1 // Fig. 3.11: GradeBook.h
2 // GradeBook class definition. This file presents GradeBook's public
3 // interface without revealing the implementations of GradeBook's member
4 // functions, which are defined in GradeBook.cpp.
5 #include <string> // class GradeBook uses C++ standard string class
6 using std::string;
7
8 // GradeBook class definition
9 class GradeBook
10 {
11 public:
12     GradeBook( string ); // constructor that initializes courseName
13     void setCourseName( string ); // function that sets the course name
14     string getCourseName(); // function that gets the course name
15     void displayMessage(); // function that displays a welcome message
16 private:
17     string courseName; // course name for this GradeBook
18 }; // end class GradeBook
```

Interface contains data members
and member function prototypes



Common Programming Error 3.8

Forgetting the semicolon at the end of a function prototype is a syntax error.



Good Programming Practice 3.7

Although parameter names in function prototypes are optional (they are ignored by the compiler), many programmers use these names for documentation purposes.



Error-Prevention Tip 3.4

Parameter names in a function prototype (which, again, are ignored by the compiler) can be misleading if wrong or confusing names are used. For this reason, many programmers create function prototypes by copying the first line of the corresponding function definitions (when the source code for the functions is available), then appending a semicolon to the end of each prototype.



Common Programming Error 3.9

When defining a class's member functions outside that class, omitting the class name and binary scope resolution operator (::) preceding the function names causes compilation errors.

```
1 // Fig. 3.12: GradeBook.cpp
2 // GradeBook member-function definitions. This file contains
3 // implementations of the member functions prototyped in GradeBook.h.
```

GradeBook implementation is placed in a separate source-code file

_12.cpp

```
4 #include <iostream>
5 using std::cout;
6 using std::endl;
```

(1 of 2)

```
8 #include "GradeBook.h" // include definition of class GradeBook
```

Include the header file to access the class name **GradeBook**

```
10 // constructor initializes courseName with string supplied as argument
```

```
11 GradeBook::GradeBook( string name )
```

```
12 {
```

```
13     setCourseName( name ); // call set function to initialize courseName
```

```
14 } // end GradeBook constructor
```

```
15
```

```
16 // function to set the course name
```

```
17 void GradeBook::setCourseName( string name )
```

```
18 {
```

```
19     courseName = name; // store the course name in the object
```

```
20 } // end function setCourseName
```

```
21
```

Binary scope resolution operator ties a function to its class



fig03_12.cpp

(2 of 2)

```
22 // function to get the course name
23 string GradeBook::getCourseName()
24 {
25     return courseName; // return object's courseName
26 } // end function getCourseName
27
28 // display a welcome message to the GradeBook user
29 void GradeBook::displayMessage()
30 {
31     // call getCourseName to get the courseName
32     cout << "Welcome to the grade book for\n" << getCourseName()
33         << "!" << endl;
34 } // end function displayMessage
```



fig03_13.cpp

(1 of 1)

```
1 // Fig. 3.13: fig03_13.cpp
2 // GradeBook class demonstration after separating
3 // its interface from its implementation.
4 #include <iostream>
5 using std::cout;
6 using std::endl;
7
8 #include "GradeBook.h" // include definition of class GradeBook
9
10 // function main begins program execution
11 int main()
12 {
13     // create two GradeBook objects
14     GradeBook gradeBook1( "CS101 Introduction to C++ Programming" );
15     GradeBook gradeBook2( "CS102 Data Structures in C++" );
16
17     // display initial value of courseName for each GradeBook
18     cout << "gradeBook1 created for course: " << gradeBook1.getCourseName()
19         << "\ngradeBook2 created for course: " << gradeBook2.getCourseName()
20         << endl;
21     return 0; // indicate successful termination
22 } // end main
```

```
gradeBook1 created for course: CS101 Introduction to C++ Programming
gradeBook2 created for course: CS102 Data Structures in C++
```



3.9 Separating Interface from Implementation (Cont.)⁷²

- **The Compilation and Linking Process**

- **Source-code file is compiled to create the class's object code (source-code file must `#include` header file)**
 - **Class implementation programmer only needs to provide header file and object code to client**
- **Client must `#include` header file in their own code**
 - **So compiler can ensure that the main function creates and manipulates objects of the class correctly**
- **To create executable application**
 - **Object code for client code must be linked with the object code for the class and the object code for any C++ Standard Library object code used in the application**



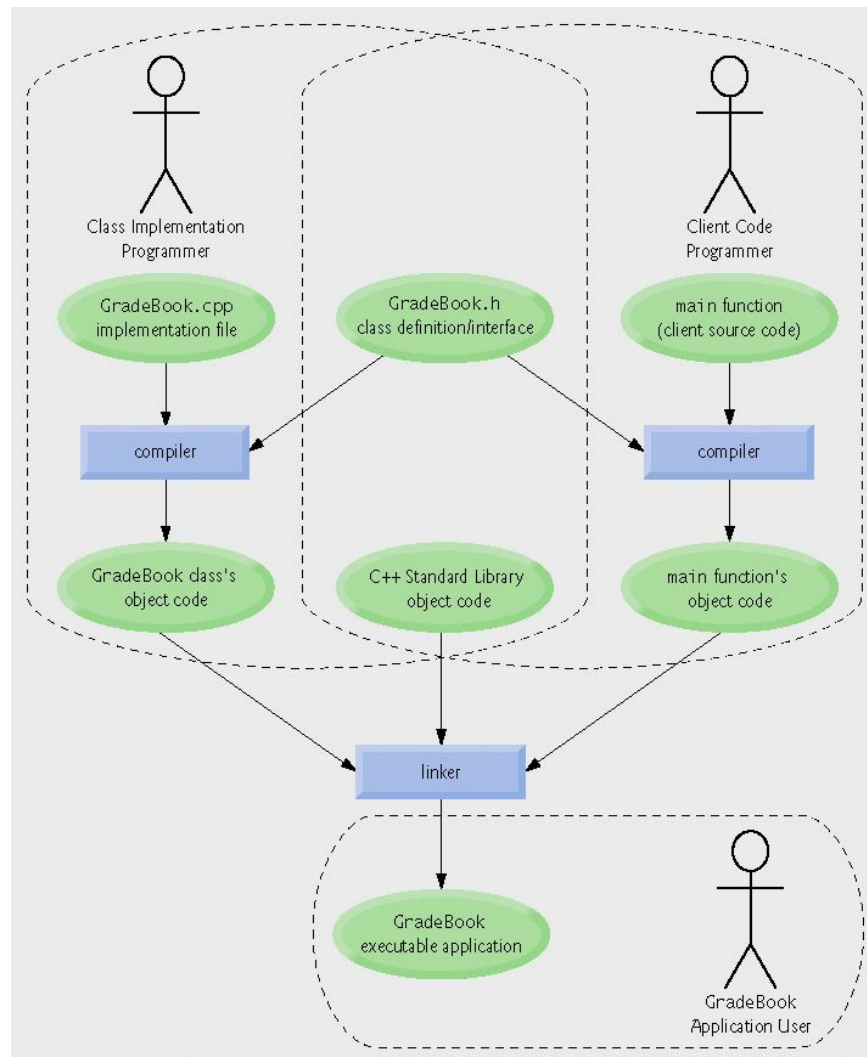


Fig.3.14 | Compilation and linking process that produces an executable application.

3.10 Validating Data with *set*⁷⁴ Functions

- ***set* functions can validate data**
 - Known as validity checking
 - Keeps object in a consistent state
 - The data member contains a valid value
 - Can return values indicating that attempts were made to assign invalid data
- **string member functions**
 - length returns the number of characters in the string
 - Substr returns specified substring within the string



fig03_15.cpp

(1 of 1)

```
1 // Fig. 3.15: GradeBook.h
2 // GradeBook class definition presents the public interface of
3 // the class. Member-function definitions appear in GradeBook.cpp.
4 #include <string> // program uses C++ standard string class
5 using std::string;
6
7 // GradeBook class definition
8 class GradeBook
9 {
10 public:
11     GradeBook( string ); // constructor that initializes a GradeBook object
12     void setCourseName( string ); // function that sets the course name
13     string getCourseName(); // function that gets the course name
14     void displayMessage(); // function that displays a welcome message
15 private:
16     string courseName; // course name for this GradeBook
17 }; // end class GradeBook
```



```
1 // Fig. 3.16: GradeBook.cpp
2 // Implementations of the GradeBook member-function definitions.
3 // The setCourseName function performs validation.
4 #include <iostream>
5 using std::cout;
6 using std::endl;
7
8 #include "GradeBook.h" // include definition of class GradeBook
9
10 // constructor initializes courseName with string supplied as argument
11 GradeBook::GradeBook( string name )
12 {
13     setCourseName( name ); // validate and store courseName
14 } // end GradeBook constructor
15
16 // function that sets the course name;
17 // ensures that the course name has at most 25 characters
18 void GradeBook::setCourseName( string name )
19 {
20     if ( name.length() <= 25 ) // if name has 25 or fewer characters
21         courseName = name; // store the course name in the object
22 }
```

Constructor calls *set* function to perform validity checking

set functions perform validity checking to keep **courseName** in a consistent state

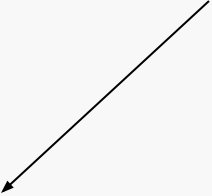


```
23 if ( name.length() > 25 ) // if name has more than 25 characters
24 {
25     // set courseName to first 25 characters of parameter name
26     courseName = name.substr( 0, 25 ); // start at 0, length of 25
27
28     cout << "Name \"" << name << "\" exceeds maximum length (25).\n"
29         << "Limiting courseName to first 25 characters.\n" << endl;
30 } // end if
31 } // end function setCourseName
32
33 // function to get the course name
34 string GradeBook::getCourseName()
35 {
36     return courseName; // return object's courseName
37 } // end function getCourseName
38
39 // display a welcome message to the GradeBook user
40 void GradeBook::displayMessage()
41 {
42     // call getCourseName to get the courseName
43     cout << "Welcome to the grade book for\n" << getCourseName()
44         << "!" << endl;
45 } // end function displayMessage
```



```
1 // Fig. 3.17: fig03_17.cpp
2 // Create and manipulate a GradeBook object; illustrate validation.
3 #include <iostream>
4 using std::cout;
5 using std::endl;
6
7 #include "GradeBook.h" // include definition of class GradeBook
8
9 // function main begins program execution
10 int main()
11 {
12     // create two GradeBook objects;
13     // initial course name of gradeBook1 is too long
14     GradeBook gradeBook1( "CS101 Introduction to Programming in C++" );
15     GradeBook gradeBook2( "CS102 C++ Data Structures" );
16 }
```

Constructor will call *set* function
to perform validity checking




```
17 // display each GradeBook's courseName
18 cout << "gradeBook1's initial course name is: "
19     << gradeBook1. get CourseName()
20     << "\ngradeBook2's initial course name is: "
21     << gradeBook2. get CourseName() << endl ;
22
23 // modify myGradeBook's courseName (with a valid-length string)
24 gradeBook1. set CourseName( "CS101 C++ Programming" );
25
26 // display each GradeBook's courseName
27 cout << "\ngradeBook1's course name is: "
28     << gradeBook1. get CourseName()
29     << "\ngradeBook2's course name is: "
30     << gradeBook2. get CourseName() << endl ;
31 return 0; // indicate successful termination
32 } // end main
```



Call *set* function to perform validity checking

Name "CS101 Introduction to Programming in C++" exceeds maximum length (25).
Limiting courseName to first 25 characters.

gradeBook1's initial course name is: **CS101 Introduction to Pro**
gradeBook2's initial course name is: CS102 C++ Data Structures

gradeBook1's course name is: CS101 C++ Programming
gradeBook2's course name is: CS102 C++ Data Structures



Software Engineering Observation 3.6

Making data members private and controlling access, especially write access, to those data members through public member functions helps ensure data integrity.



Error-Prevention Tip 3.5

The benefits of data integrity are not automatic simply because data members are made private—the programmer must provide appropriate validity checking and report the errors.



Software Engineering Observation 3.7

Member functions that *set* the values of private data should verify that the intended new values are proper; if they are not, the *set* functions should place the private data members into an appropriate state.

3.11 (Optional) Software Engineering Case Study: Identifying the Classes in the ATM Requirements Document

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- **Identifying the classes in a system**
 - **Key nouns and noun phrases in requirements document**
 - Some are attributes of other classes
 - Some do not correspond to parts of the system
 - Some are classes
 - To be represented by UML class diagrams



Nouns and noun phrases in the requirements document		
bank	money / fund	account number
ATM	screen	PIN
user	keypad	bank database
customer	cash dispenser	balance inquiry
transaction	\$20 bill / cash	withdrawal
account	deposit slot	deposit
balance	deposit envelope	

Fig.3.18 | Nouns and noun phrases in the requirements document.

3.11 (Optional) Software Engineering Case Study: Identifying the Classes in the ATM Requirements Document (Cont.)

85

- **Modeling classes with UML class diagrams**
 - **Top compartment contains name of the class**
 - **Middle compartment contains attributes**
 - **Bottom compartment contains operations**
 - **An elided diagram**
 - **Suppress some class attributes and operations for readability**
 - **An association**
 - **Represented by a solid line that connects two classes**
 - **Association can be named**
 - **Numbers near end of each line are multiplicity values**
 - **Role name identifies the role an object plays in an association**





Fig.3.19 | Representing a class in the UML using a class diagram.

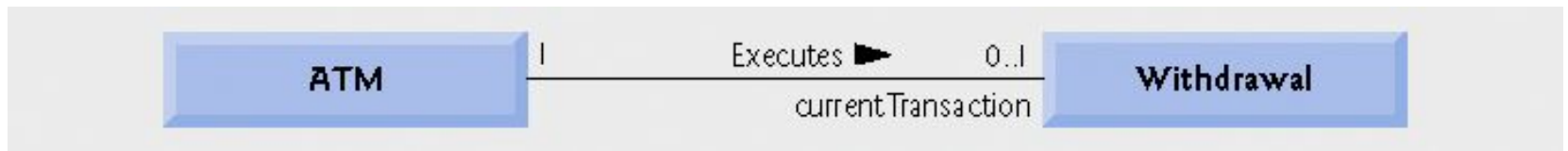


Fig.3.20 | Class diagram showing an association among classes.

Symbol	Meaning
0	None
1	One
<i>m</i>	An integer value
0..1	Zero or one
<i>m, n</i>	<i>m</i> or <i>n</i>
<i>m..n</i>	At least <i>m</i> , but not more than <i>n</i>
*	Any nonnegative integer (zero or more)
0..*	Zero or more (identical to *)
1..*	One or more

Fig.3.21 | Multiplicity types.

3.11 (Optional) Software Engineering Case Study: Identifying the Classes in the ATM Requirements Document (Cont.)

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- **Composition relationship**
 - Indicated by solid diamonds attached to association lines
 - Composition properties
 - Only one class can represent the whole
 - Parts only exist while whole exists, whole creates and destroys parts
 - A part may only belong to one whole at a time
- **Hollow diamonds indicate aggregation**
 - A weaker form of composition
- **Types of associations**
 - One-to-one
 - One-to-many
 - Many-to-one



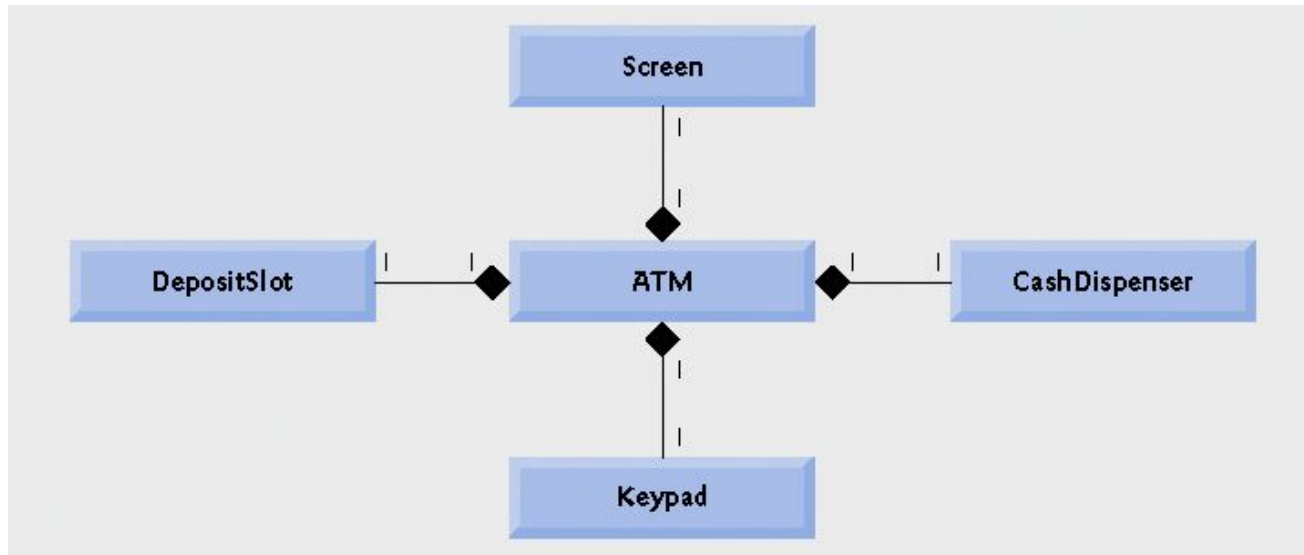


Fig.3.22 | Class diagram showing composition relationships.

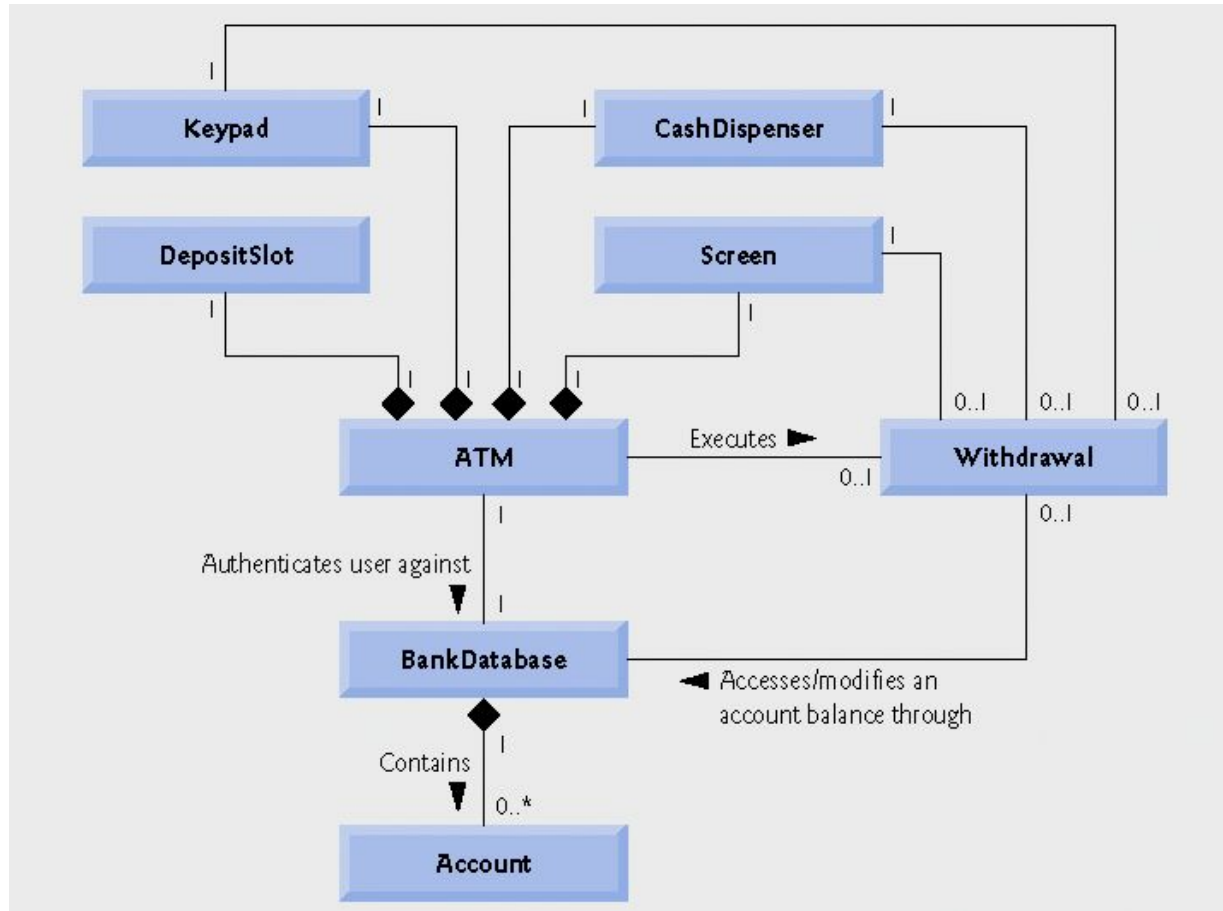


Fig.3.23 | Class diagram for the ATM system model

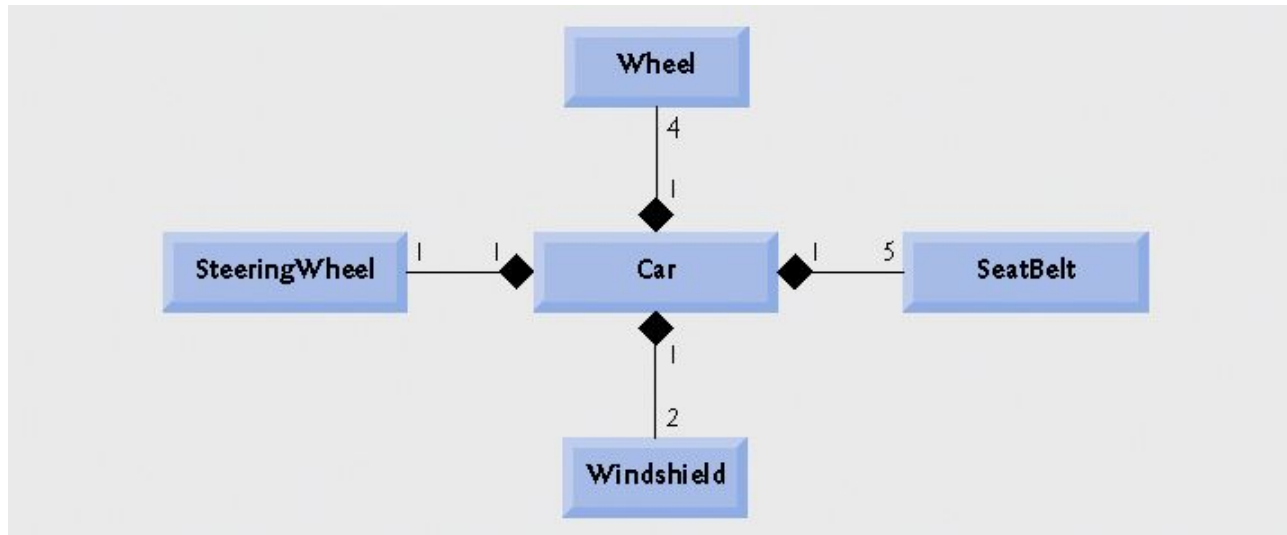


Fig.3.24 | Class diagram showing composition relationships of a class Car.

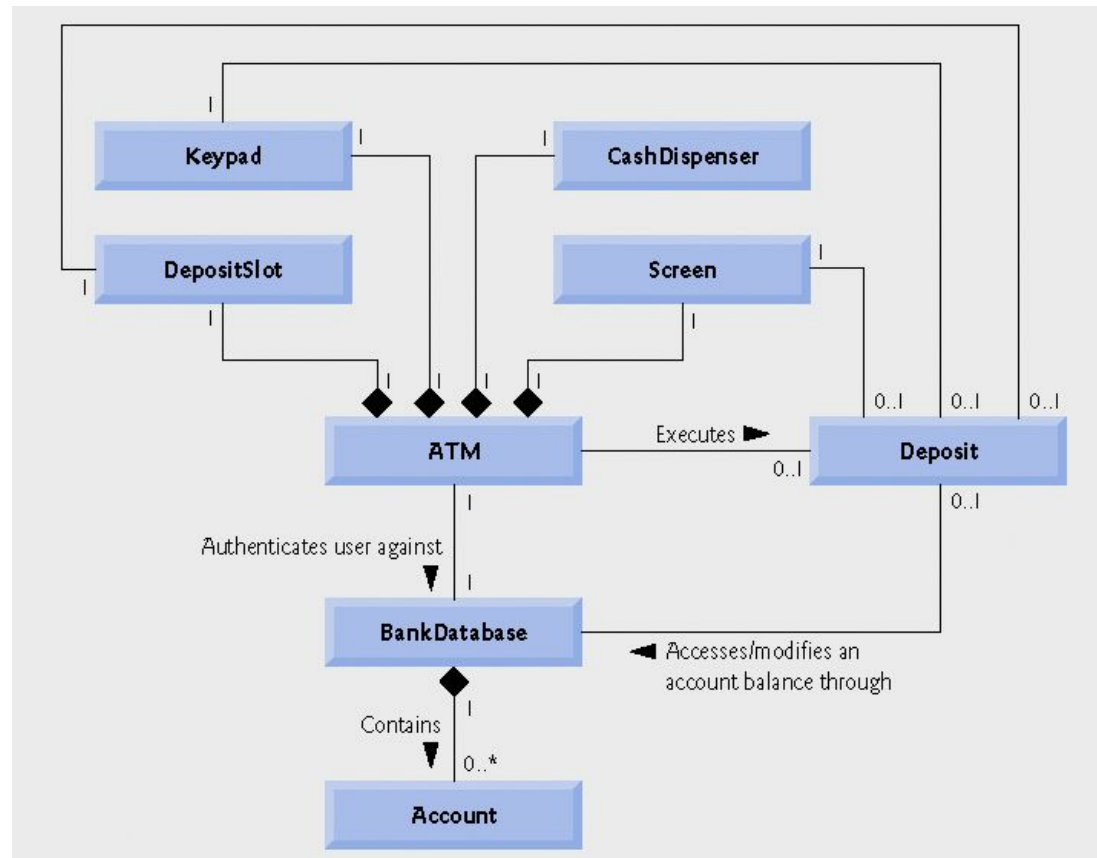


Fig.3.25 | Class diagram for the ATM system model including class Deposit.