4

Introduction to Classes and Objects

Object oriented programming benefits

- Objects are created on real world entities
- Reusability of software
- Building softwares quickly
- Easily extensible
- …

4.2 Classes, Objects, Methods, Attributes

- Class: A Template / blueprint of objects
  - Car example: A car begins as engineering drawings, similar to the blueprints used to design a house.
  - Each class you create becomes a new type containing methods and properties you can use to create objects
- Object: instance of a class
  - Car example: A car must be built from its engineering drawings before it can be driven
  - you must build an object from a class before a program can perform the tasks that the class's methods define
  - Many objects can be created from the same class

4.2 Classes, Objects, Methods, Attributes

- Classes have Methods: describe the mechanisms that perform a tasks
  - Car example: acceleration
  - **Hide complex tasks from the user**: a driver does not need to know how the accelerator works but can use it.
  - You send **messages** to an object by making **method calls** to perform tasks

4.2 Classes, Objects, Methods, Attributes

- Classes have attributes
  - Cars have color and speed gauge, current speed
  - Attributes are specified by the class’s instance variables.
  - Attributes are not necessarily accessible / changable directly.
    - The car manufacturer does not want drivers to access the car’s engine to observe the amount of fuel in its tank.
  - Every object maintains its own attributes.

- create a GradeBook **Console Application**.
- The GradeBook **class declaration** (Fig. 4.1) contains a DisplayMessage method that displays a message on the screen.

GradeBook.cs

```
// Fig. 4.1: GradeBook.cs
// Class declaration with one method.
using System;

public class GradeBook
{
   // display a welcome message to the GradeBook user
   public void DisplayMessage()
   {
      Console.WriteLine( "Welcome to the Grade Book!" );
   } // end method DisplayMessage
} // end class GradeBook
```

method header.

Fig. 4.1 | Class declaration with one method.

4.3 Declaring a Class with a Method and Instantiating an Object of a Class

- Keyword `public` is an **access modifier**.
  - Access modifiers determine the accessibility of properties and methods.
- The class's body is enclosed in a pair of left and right braces (`{` and `}`).

4.3 Declaring a Class with a Method and Instantiating an Object of a Class

- The method declaration begins with `public` to indicate that the method can be called from outside the class declaration's body.
- Keyword `void`—known as the method's return type—indicates that this method will not return information to its calling method.
- When a method specifies a return type other than `void`, the method returns a result to its calling method.
- The body of a method contains statement(s) that perform the method's task.

- The GradeBookTest class declaration (Fig. 4.2) contains the Main method that controls our application’s execution.

GradeBookTest.cs

```
 1 // Fig. 4.2: GradeBookTest.cs
 2 // Create a GradeBook object and call its DisplayMessage method.
 3 public class GradeBookTest
 4 {
 5    // Main method begins program execution
 6    public static void Main( string[] args )
 7    {
 8       // create a GradeBook object and assign it to myGradeBook
 9       GradeBook myGradeBook = new GradeBook();
10
11       // call myGradeBook's DisplayMessage method
12       myGradeBook.DisplayMessage();
13    } // end Main
14 } // end class GradeBookTest
```

Object creation expression (constructor).

Using the object created in line 9.

```
Welcome to the Grade Book!
```

Fig. 4.2 | Create a GradeBook object and call its DisplayMessage method.

4.3 Declaring a Class with a Method and Instantiating an Object of a Class (Cont.)

- Figure 4.3 presents a **UML class diagram** for class `GradeBook`.
- Classes are modeled as a rectangle with three compartments.
  - The top compartment contains the name of the class.
  - The middle compartment contains the class's attributes.
  - The bottom compartment contains the class's operations.
- The plus sign (+) indicates that `DisplayMessage` is a public operation.

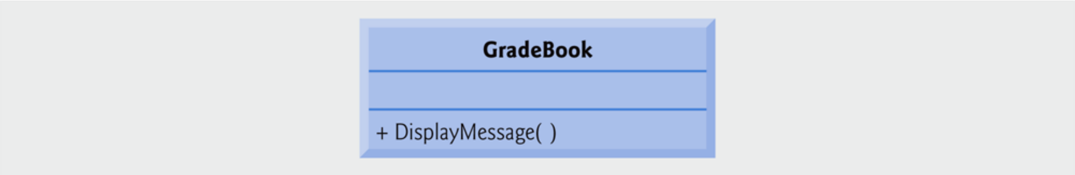


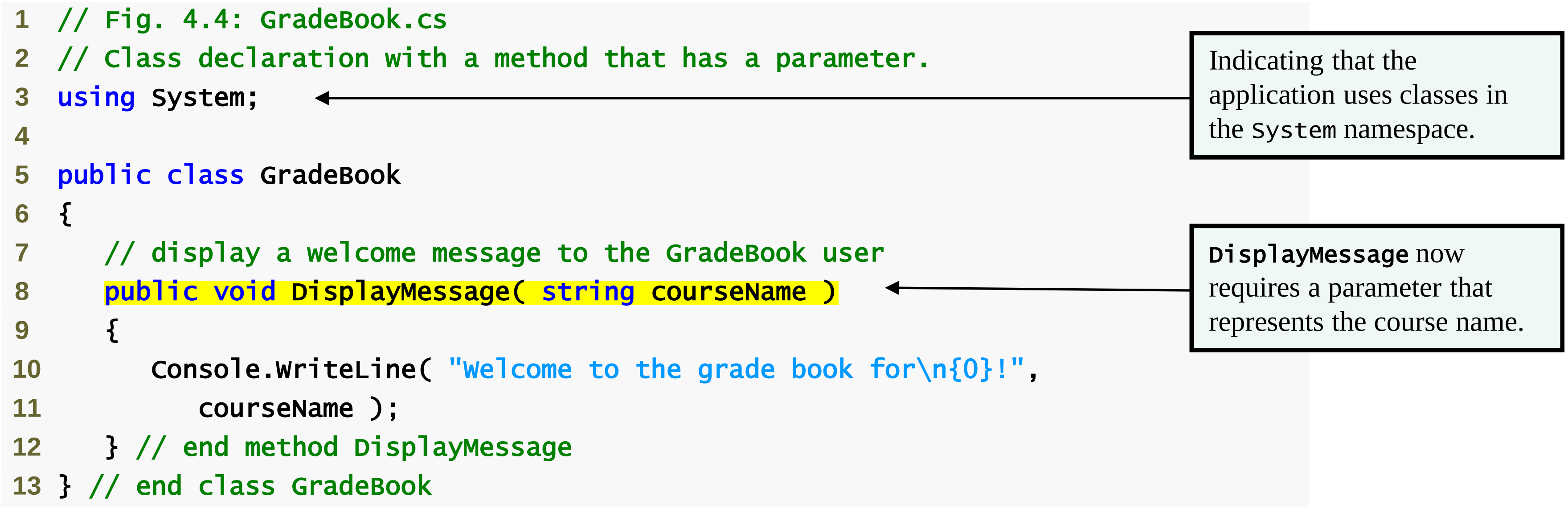
Fig. 4.3 | UML class diagram indicating that class `GradeBook` has a `public` `DisplayMessage` operation.

4.4 Declaring a Method with a Parameter

- A method can specify parameters, additional information required to perform its task.
- A method call supplies values—called arguments—for each of the method's parameters.
- For example, the `Console.WriteLine` method requires an argument that specifies the data to be displayed in a console window.

- Class `GradeBook` (Fig. 4.4) with a `DisplayMessage` method that displays the course name as part of the welcome message.

`GradeBook.cs`



```
// Fig. 4.4: GradeBook.cs
// Class declaration with a method that has a parameter.
using System;

public class GradeBook
{
   // display a welcome message to the GradeBook user
   public void DisplayMessage( string courseName )
   {
      Console.WriteLine( "Welcome to the grade book for\n{0}!",
         courseName );
   } // end method DisplayMessage
} // end class GradeBook
```

Indicating that the application uses classes in the `System` namespace.

`DisplayMessage` now requires a parameter that represents the course name.

Fig. 4.4 | Class declaration with a method that has a parameter.

- The new class is used from the `Main` method of class `GradeBookTest` (Fig. 4.5).

GradeBookTest.cs

(1 of 2)

```
// Fig. 4.5: GradeBookTest.cs
// Create a GradeBook object and pass a string to
// its DisplayMessage method.
using System;

public class GradeBookTest
{
   // Main method begins program execution
   public static void Main( string[] args )
   {
      // create a GradeBook object and assign it to myGradeBook
      GradeBook myGradeBook = new GradeBook();

      // prompt for and input course name
      Console.WriteLine( "Please enter the course name:" );
      string nameOfCourse = Console.ReadLine(); // read a line of text
      Console.WriteLine(); // output a blank line
```

Creating an object of class `GradeBook` and assigns it to variable `myGradeBook`.

Prompting the user to enter a course name.

Reading the name from the user.

Fig. 4.5 | Create `GradeBook` object and pass a string to its `DisplayMessage` method. (Part 1 of 2).

GradeBookTest.cs

(2 of 2)

```csharp

      // call myGradeBook's DisplayMessage method
      // and pass nameOfCourse as an argument
      myGradeBook.DisplayMessage( nameOfCourse );
   } // end Main
} // end class GradeBookTest
```

Calling myGradeBook's DisplayMessage method and passing nameOfCourse to the method.

```
Please enter the course name:
CS101 Introduction to C# Programming

Welcome to the grade book for
CS101 Introduction to C# Programming!
```

Fig. 4.5 | Create GradeBook object and pass a string to its DisplayMessage method. (Part 2 of 2).

4.4 Declaring a Method with a Parameter (Cont.)

Software Engineering Observation 4.1

Normally, objects are created with new. One exception is a string literal that are references to string objects that are implicitly created by C#.

- The argument value in the call is assigned to the corresponding parameter in the method header.

4.4 Declaring a Method with a Parameter (Cont.)

Common Programming Error 4.1

A compilation error occurs if the number of arguments in a method call does not match the number of parameters in the method declaration.

Common Programming Error 4.2

A compilation error occurs if the types of the arguments in a method call are not consistent with the types of the corresponding parameters in the method declaration.

4.4 Declaring a Method with a Parameter (Cont.)

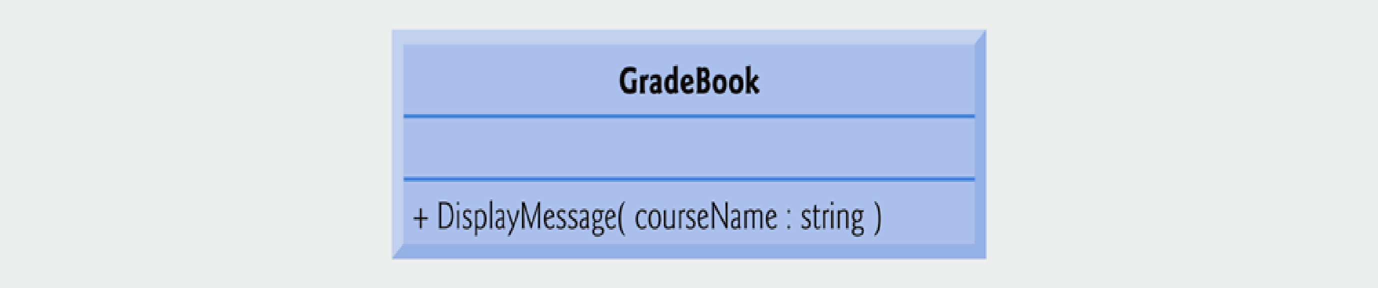


Fig. 4.6 | UML class diagram indicating that class `GradeBook` has a public `DisplayMessage` operation with a `courseName` parameter of type `string`.

4.4 Declaring a Method with a Parameter (Cont.)

- Classes in the same project are considered to be in the same namespace.
- `using` indicates that the application uses classes in another namespace.
- Without `using`, we would write the **fully qualified class name**:

```
System.Console.WriteLine( "Please enter the course
  name:" );
```

4.5 Instance Variables and Properties (Cont.)

- When each object of a class maintains its own copy of an attribute, the field is known as an instance variable.
- If the access modifier is omitted before a member of a class, the member is implicitly declared `private`.
- Declaring the instance variables of a class as `private` and the methods of the class as `public` facilitates debugging, because problems with data manipulations are localized to the class’s methods and properties.
- Declaring instance variables with access modifier `private` is known as information hiding.

4.5 Instance Variables and Properties (Cont.)

- We need to provide controlled ways for programmers to “get” and “set” the value of an instance variable.
- Properties contain `get` and `set` **accessors** that handle the details of returning and modifying data.
- After defining a property, you can use it like a variable in your code.
- Accessing `private` data through `set` and `get` accessors not only protects the instance variables from receiving invalid values, but also hides the internal representation of the instance variables from that class’s clients. Thus, if representation of the data changes, only the properties’ implementations need to change.

- Class `GradeBook` (Fig. 4.7) maintains the course name as an instance variable so that it can be used or modified.

GradeBook.cs

(1 of 2)

```
// Fig. 4.7: GradeBook.cs
// GradeBook class that contains a courseName instance variable,
// and a property to get and set its value.
using System;

public class GradeBook
{
   private string courseName; // course name for this GradeBook

   // property to get and set the course name
```

Declaring `courseName` as an instance variable.

Fig. 4.7 | `GradeBook` class that contains a `private` instance variable, `courseName` and a `public` property to `get` and `set` its value. (Part 1 of 2).

GradeBook.cs

(2 of 2)

```
   public string CourseName
   {
      get
      {
         return courseName;
      } // end get
      set
      {
         courseName = value;
      } // end set
   } // end property CourseName

   // display a welcome message to the GradeBook user
   public void DisplayMessage()
   {
      // use property CourseName to get the
      // name of the course that this GradeBook represents
      Console.WriteLine( "Welcome to the grade book for\n{0}!",
         CourseName ); // display property CourseName
   } // end method DisplayMessage
} // end class GradeBook
```

A `public` property declaration.

Fig. 4.7 | `GradeBook` class that contains a `private` instance variable, `courseName` and a `public` property to `get` and `set` its value. (Part 2 of 2).

4.5 Instance Variables and Properties (Cont.)

Good Programming Practice 4.1

We prefer to list the fields of a class first, so that, as you read the code, you see the names and types of the variables before you see them used in the methods of the class.

Good Programming Practice 4.2

Placing a blank line between method and property declarations enhances code readability.

4.5 Instance Variables and Properties (Cont.)

- The get accessor begins with the identifier **get** and is delimited by braces.
  - The expression's value is returned to the client code that uses the property.

```
string theCourseName = gradeBook.CourseName;
```

- gradeBook.CourseName implicitly executes the get accessor, which returns its value.

4.5 Instance Variables and Properties (Cont.)

- The set accessor begins with the identifier **set** and is delimited by braces.

```
gradeBook.CourseName = "CS100 Introduction to Computers";
```

- The text "CS100 Introduction to Computers" is assigned to the set accessor's keyword named **value** and the set accessor executes.
- A set accessor does not return any data.

GradeBookTest.cs

(1 of 2)

- Class GradeBookTest (Fig. 4.8) creates a GradeBook object and demonstrates property CourseName.

```
// Fig. 4.8: GradeBookTest.cs
// Create and manipulate a GradeBook object.
using System;

public class GradeBookTest
{
   // Main method begins program execution
   public static void Main( string[] args )
   {
      // create a GradeBook object and assign it to myGradeBook
      GradeBook myGradeBook = new GradeBook();

      // display initial value of CourseName
      Console.WriteLine( "Initial course name is: '{0}'\n",
         myGradeBook.CourseName );

```

Creating a GradeBook object and assigning it to local variable myGradeBook.

A public property declaration.

Fig. 4.8 | Create and manipulate a GradeBook object. (Part 1 of 2).

GradeBookTest.cs

(2 of 2)

```
      // prompt for and read course name
      Console.WriteLine( "Please enter the course name:" );
      myGradeBook.CourseName = Console.ReadLine(); // set CourseName
      Console.WriteLine(); // output a blank line

      // display welcome message after specifying course name
      myGradeBook.DisplayMessage();
   } // end Main
} // end class GradeBookTest
```

Assigns the input course name to myGradeBook's CourseName property.

Calling DisplayMessage for a welcome message.

```
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!
```

Fig. 4.8 | Create and manipulate a GradeBook object. (Part 2 of 2).

4.5 Instance Variables and Properties (Cont.)

- Unlike local variables, every instance variable has a **default initial value**.
- The default value for an instance variable of type `string` is `null`.
- When you display a `string` variable that contains the value `null`, no text is displayed.

4.6 UML Class Diagram with a Property

- Figure 4.9 contains an updated UML class diagram for the version of class `GradeBook`.
- We model properties in the UML as attributes preceded by the word “property” in **guillemets** (« and »).
- To indicate that an attribute is `private`, a class diagram would list the **private visibility symbol**—a minus sign (–)—before the attribute’s name.

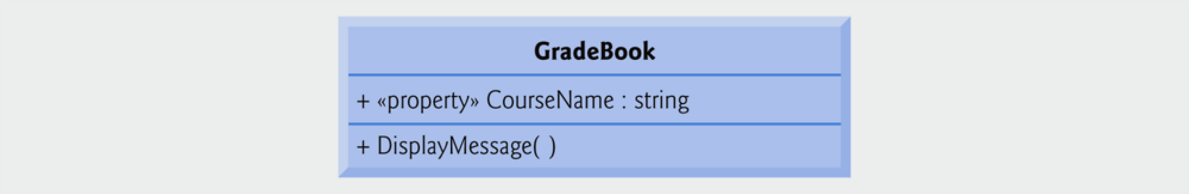


Fig. 4.9 | UML class diagram indicating that class `GradeBook` has a public `CourseName` property of type `string` and one public method.

4.8 Auto-implemented Properties

- Notice that `CourseName`'s `get` accessor simply returns `courseName`'s value and the `set` accessor simply assigns a value to the instance variable.
- For such cases, C# now provides **automatically implemented properties**.
- If you later decide to implement other logic in the `get` or `set` accessors, you can simply reimplement the property.

- Figure 4.10 redefines class `GradeBook` with an auto-implemented `CourseName` property.

GradeBook.cs

```
// Fig. 4.10: GradeBook.cs
// GradeBook class with an auto-implemented property.
using System;

public class GradeBook
{
   // auto-implemented property CourseName implicitly creates
   // an instance variable for this GradeBook's course name
   public string CourseName { get; set; }

   // display a welcome message to the GradeBook user
   public void DisplayMessage()
   {
      // use auto-implemented property CourseName to get the
      // name of the course that this GradeBook represents
      Console.WriteLine( "Welcome to the grade book for\n{0}!",
         CourseName ); // display auto-implemented property CourseName
   } // end method DisplayMessage
} // end class GradeBook
```

Declaring the auto-implemented property.

Implicitly obtaining the property’s value.

Fig. 4.10 | GradeBook class with an auto-implemented property.

Outline

- The unchanged test program (Fig. 4.11) shows that the auto-implemented property works identically.

`GradeBookTest.cs`

(1 of 2)

```
// Fig. 4.11: GradeBookTest.cs
// Create and manipulate a GradeBook object.
using System;

public class GradeBookTest
{
   // Main method begins program execution
   public static void Main( string[] args )
   {
      // create a GradeBook object and assign it to myGradeBook
      GradeBook myGradeBook = new GradeBook();

      // display initial value of CourseName
      Console.WriteLine( "Initial course name is: '{0}'\n",
         myGradeBook.CourseName );

```

Fig. 4.11 | Create and manipulate a `GradeBook` object. (Part 1 of 2).

GradeBookTest.cs

(2 of 2)

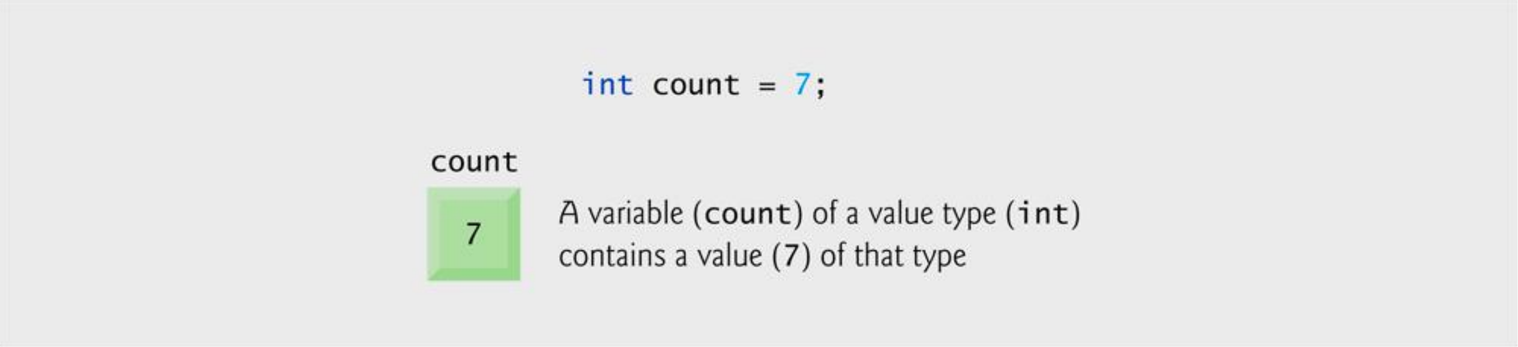
```
      // prompt for and read course name
      Console.WriteLine( "Please enter the course name:" );
      myGradeBook.CourseName = Console.ReadLine(); // set CourseName
      Console.WriteLine(); // output a blank line

      // display welcome message after specifying course name
      myGradeBook.DisplayMessage();
   } // end Main
} // end class GradeBookTest
```

```
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!
```

Fig. 4.11 | Create and manipulate a `GradeBook` object. (Part 2 of 2).

4.9 Value Types vs. Reference Types

- A variable of a value type (such as `int`) simply contains a value of that type (Fig. 4.12).



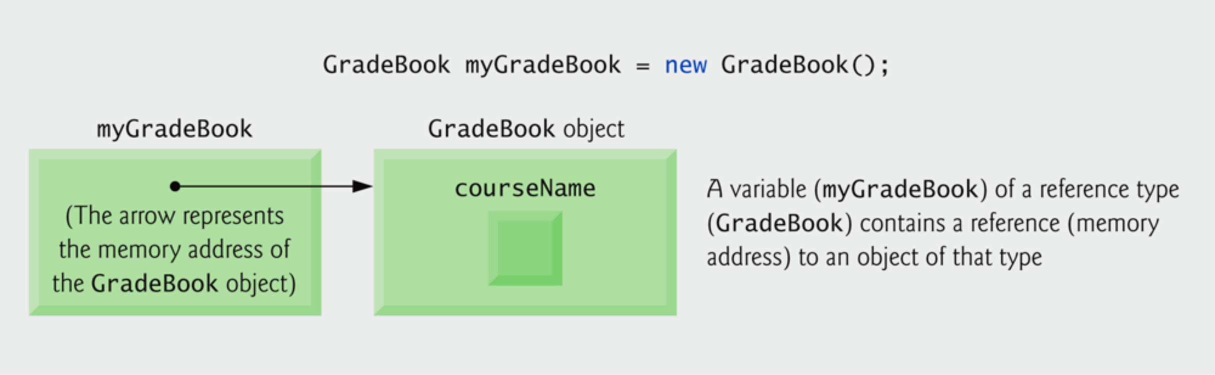
```
int count = 7;
```

A variable (`count`) of a value type (`int`) contains a value (`7`) of that type

Fig. 4.12 | Value-type variable.

4.9 Value Types vs. Reference Types (Cont.)

- A variable of a reference type contains the address of a location in memory where its data is stored (Fig. 4.13).
- Reference-type instance variables are initialized by default to the value `null`.
- A variable that refers to an object is used to **call** the object’s methods and access the object’s properties.



```
GradeBook myGradeBook = new GradeBook();
```

(The arrow represents the memory address of the GradeBook object)

A variable (myGradeBook) of a reference type (GradeBook) contains a reference (memory address) to an object of that type

Fig. 4.13 | Reference-type variable.

4.9 Value Types vs. Reference Types (Cont.)

Software Engineering Observation 4.5

A variable’s declared type indicates whether the variable is of a value or a reference type. If a variable’s type is not one of the simple types, or an enum or a `struct` type, then it is a reference type.

4.10 Initializing Objects with Constructors

- Each class should provide a **constructor** to initialize an object of a class when the object is created.
- The `new` operator calls the class's constructor to perform the initialization.
- The compiler provides a **`public` default constructor** with no parameters, so *every* class has a constructor.

4.10 Initializing Objects with Constructors (Cont.)

- When you declare a class, you can provide your own constructor to specify custom initialization:

```
GradeBook myGradeBook =
    new GradeBook( "CS101 Introduction to C#
                   Programming" );
```

- `"CS101 Introduction to C# Programming"` is passed to the constructor.

Outline

- Figure 4.14 contains a modified `GradeBook` class with a custom constructor.

`GradeBook.cs`

(1 of 2)

```
// Fig. 4.14: GradeBook.cs
// GradeBook class with a constructor to initialize the course name.
using System;

public class GradeBook
{
   // auto-implemented property CourseName implicitly created an
   // instance variable for this GradeBook's course name
   public string CourseName { get; set; }

   // constructor initializes auto-implemented property
   // CourseName with string supplied as argument
   public GradeBook( string name )
   {
      CourseName = name; // set CourseName to name
   } // end constructor

```

Declaring the constructor for class `GradeBook`.

Fig. 4.14 | `GradeBook` class with a constructor to initialize the course name. (Part 1 of 2).

GradeBook.cs

(2 of 2)

```
   // display a welcome message to the GradeBook user
   public void DisplayMessage()
   {
      // use auto-implemented property CourseName to get the
      // name of the course that this GradeBook represents
      Console.WriteLine( "Welcome to the grade book for\n{0}!",
         CourseName );
   } // end method DisplayMessage
} // end class GradeBook
```

Fig. 4.14 | GradeBook class with a constructor to initialize the course name. (Part 2 of 2).

4.10 Initializing Objects with Constructors (Cont.)

- A constructor must have the same name as its class.
- Like a method, a constructor has a parameter list.

Outline

- Figure 4.15 demonstrates initializing `GradeBook` objects using the constructor.

GradeBookTest.cs

(1 of 2)

```
// Fig. 4.15: GradeBookTest.cs
// GradeBook constructor used to specify the course name at the
// time each GradeBook object is created.
using System;

public class GradeBookTest
{
   // Main method begins program execution
   public static void Main( string[] args )
   {
      // create GradeBook object
      GradeBook gradeBook1 = new GradeBook( // invokes constructor
         "CS101 Introduction to C# Programming" );
      GradeBook gradeBook2 = new GradeBook( // invokes constructor
         "CS102 Data Structures in C#" );

```

Creating and initializing `GradeBook` objects.

Fig. 4.15 | GradeBook constructor used to specify the course name at the time each GradeBook object is created. (Part 1 of 2).

GradeBookTest.cs

(2 of 2)

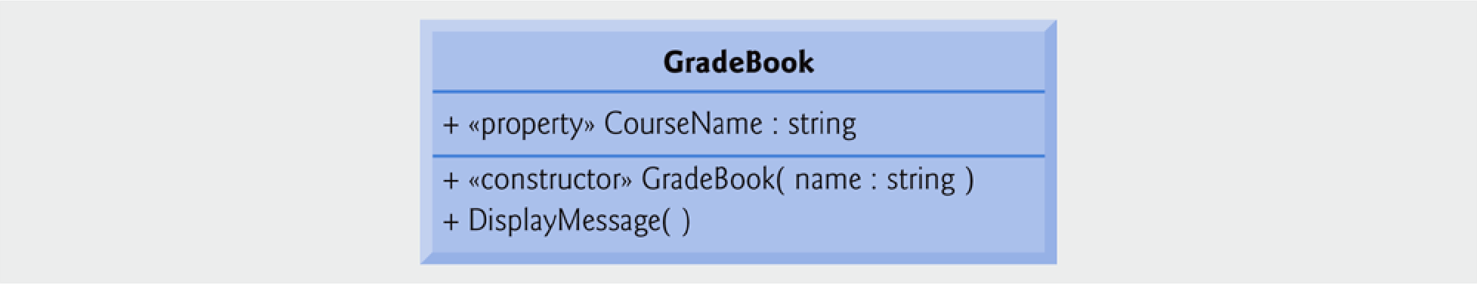
```
      // display initial value of courseName for each GradeBook
      Console.WriteLine( "gradeBook1 course name is: {0}",
         gradeBook1.CourseName );
      Console.WriteLine( "gradeBook2 course name is: {0}",
         gradeBook2.CourseName );
   } // end Main
} // end class GradeBookTest
```

```
gradeBook1 course name is: CS101 Introduction to C# Programming
gradeBook2 course name is: CS102 Data Structures in C#
```

Fig. 4.15 | GradeBook constructor used to specify the course name at the time each GradeBook object is created. (Part 2 of 2).

4.10 Initializing Objects with Constructors (Cont.)

- The UML class diagram of Fig. 4.16 models class `GradeBook`.
- To distinguish a constructor from other operations, the UML places the word “constructor” between guillemets (« and »).



GradeBook

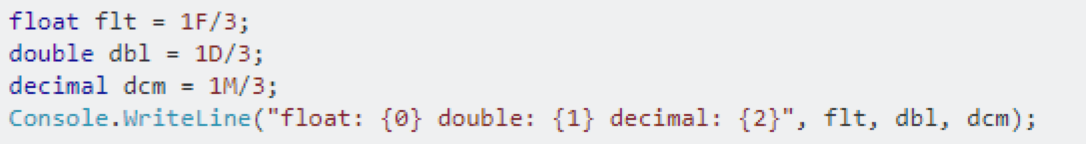
+ «property» CourseName : string

+ «constructor» GradeBook(name : string)
+ DisplayMessage( )

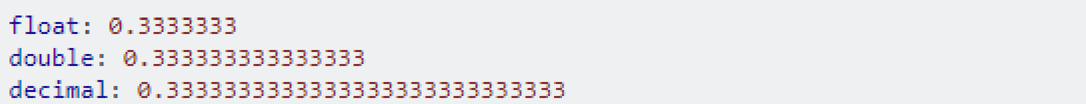
Fig. 4.16 | UML class diagram indicating that class `GradeBook` has a constructor with a `name` parameter of type `string`.

4.11 Floating-Point Numbers and Type decimal

- Types `float` and `double` are called **floating-point** types.
- C# treats all real numbers you type in an application's source code (such as `7.33` and `0.0975`) as `double` values.
- `decimal` variables are more precise and better suited for monetary amounts.
- To type a **`decimal` literal**, you must type the letter "`M`" or "`m`" at the end of a real number.



```
float flt = 1F/3;
double dbl = 1D/3;
decimal dcm = 1M/3;
Console.WriteLine("float: {0} double: {1} decimal: {2}", flt, dbl, dcm);
```



```
float: 0.3333333
double: 0.333333333333333
decimal: 0.3333333333333333333333333333
```

- A class named `Account` (Fig. 4.17) maintains the balance of a bank account.

`Account.cs`

(1 of 2)

```
// Fig. 4.17: Account.cs
// Account class with a constructor to
// initialize instance variable balance.

public class Account
{
   private decimal balance; // instance variable that stores the balance

   // constructor
   public Account( decimal initialBalance )
   {
      Balance = initialBalance; // set balance using property
   } // end Account constructor

   // credit (add) an amount to the account
   public void Credit( decimal amount )
   {
      Balance = Balance + amount; // add amount to balance
   } // end method Credit
```

An instance variable represents each `Account`’s own `balance`.

The constructor receives a parameter that represents the account’s starting balance.

Method `Credit` receives one parameter named `amount` that is added to the property `Balance`.

Fig. 4.17 | Account class with a constructor to initialize instance variable balance. (Part 1 of 2).

Account.cs

(2 of 2)

```
   // a property to get and set the account balance
   public decimal Balance
   {
      get
      {
         return balance;
      } // end get
      set
      {
         // validate that value is greater than or equal to 0;
         // if it is not, balance is left unchanged
         if ( value >= 0 )
            balance = value;
      } // end set
   } // end property Balance
} // end class Account
```

`Balance`'s `get` accessor returns the value of the `Account`'s `balance`.

`Balance`'s `set` accessor performs validation to ensure that `value` is nonnegative.

Fig. 4.17 | Account class with a constructor to initialize instance variable balance. (Part 2 of 2).

Outline

AccountTest.cs

(1 of 3)

- AccountTest (Fig. 4.18) creates two Account objects and initializes them with 50.00M and -7.53M (decimal literals).

```
// Fig. 4.18: AccountTest.cs
// Create and manipulate Account objects.
using System;

public class AccountTest
{
   // Main method begins execution of C# application
   public static void Main( string[] args )
   {
      Account account1 = new Account( 50.00M ); // create Account object
      Account account2 = new Account( -7.53M ); // create Account object

      // display initial balance of each object using a property
      Console.WriteLine( "account1 balance: {0:C}",
         account1.Balance ); // display Balance property
      Console.WriteLine( "account2 balance: {0:C}\n",
         account2.Balance ); // display Balance property

```

Passing an initial balance which will be invalidated by Balance's set accessor.

Outputting the Balance property of each Account.

Fig. 4.18 | Create and manipulate an Account object. (Part 1 of 3).

AccountTest.cs

(2 of 3)

```
      decimal depositAmount; // deposit amount read from user

      // prompt and obtain user input
      Console.Write( "Enter deposit amount for account1: " );
      depositAmount = Convert.ToDecimal( Console.ReadLine() );
      Console.WriteLine( "adding {0:C} to account1 balance\n",
         depositAmount );
      account1.Credit( depositAmount ); // add to account1 balance

      // display balances
      Console.WriteLine( "account1 balance: {0:C}",
         account1.Balance );
      Console.WriteLine( "account2 balance: {0:C}\n",
         account2.Balance );

      // prompt and obtain user input
      Console.Write( "Enter deposit amount for account2: " );
      depositAmount = Convert.ToDecimal( Console.ReadLine() );
```

Local variable `depositAmount` is *not* initialized to `0` but will be set by the user's input.

Obtaining input from the user.

Obtaining the deposit value from the user.

Fig. 4.18 | Create and manipulate an Account object. (Part 2 of 3).

AccountTest.cs

(3 of 3)

```
      Console.WriteLine( "adding {0:C} to account2 balance\n",
         depositAmount );
      account2.Credit( depositAmount ); // add to account2 balance

      // display balances
      Console.WriteLine( "account1 balance: {0:C}", account1.Balance );
      Console.WriteLine( "account2 balance: {0:C}", account2.Balance );
   } // end Main
} // end class AccountTest
```

Outputting the balances of both `Account`s.

```
account1 balance: $50.00
account2 balance: $0.00

Enter deposit amount for account1: 49.99
adding $49.99 to account1 balance
```

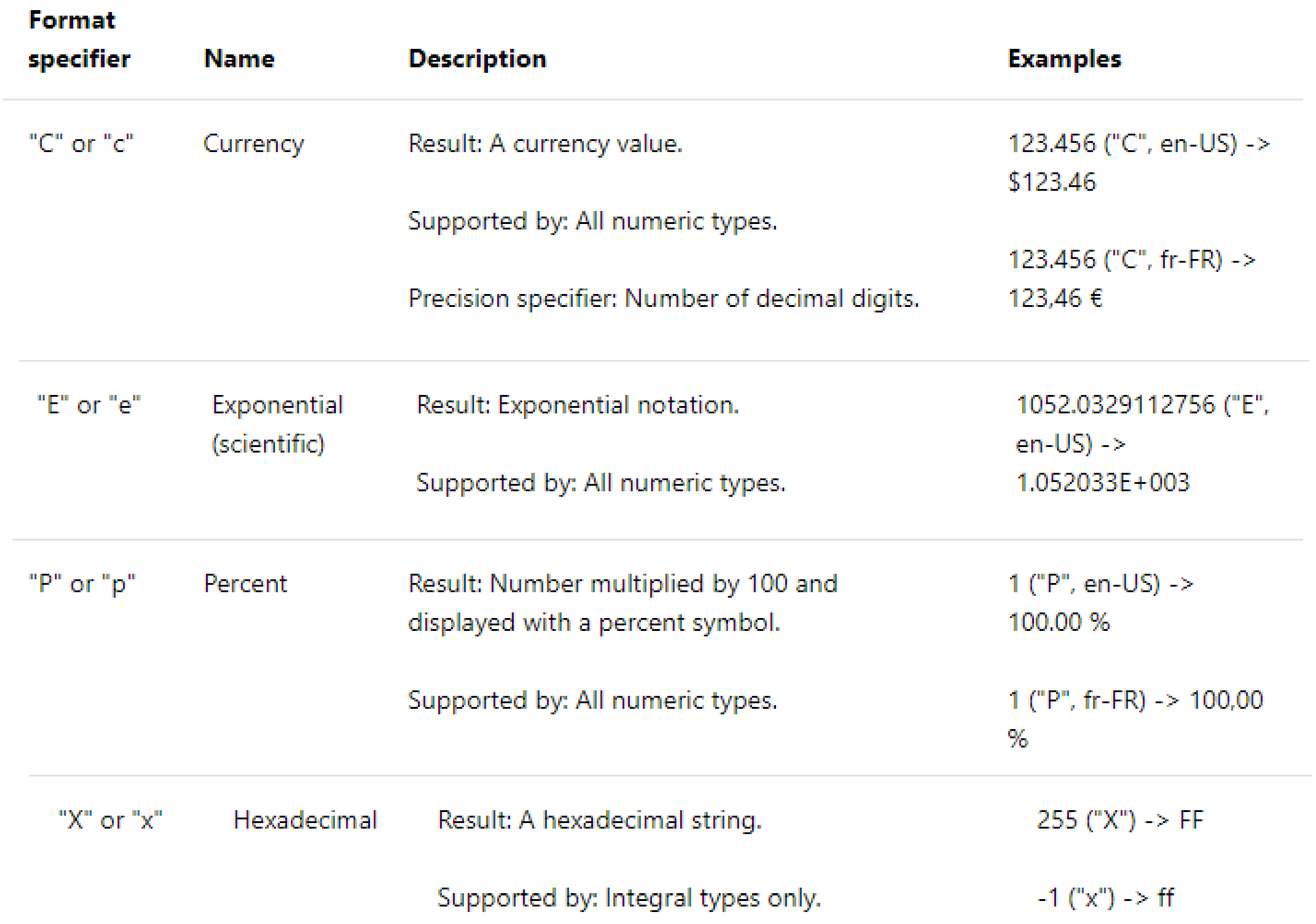
```
account1 balance: $99.99
account2 balance: $0.00

Enter deposit amount for account2: 123.21
adding $123.21 to account2 balance

account1 balance: $99.99
account2 balance: $123.21
```

Fig. 4.18 | Create and manipulate an Account object. (Part 3 of 3).

4.11 Floating-Point Numbers and Type decimal (Cont.)

- A value output with the format item `{0:C}` appears as a monetary amount.
- The `:` indicates that the next character represents a **format specifier**.

4.11 Floating-Point Numbers and Type decimal (Cont.)



Format specifier	Name	Description	Examples
"C" or "c"	Currency	Result: A currency value. Supported by: All numeric types. Precision specifier: Number of decimal digits.	123.456 ("C", en-US) -> $123.46 123.456 ("C", fr-FR) -> 123,46 €
"E" or "e"	Exponential (scientific)	Result: Exponential notation. Supported by: All numeric types.	1052.0329112756 ("E", en-US) -> 1.052033E+003
"P" or "p"	Percent	Result: Number multiplied by 100 and displayed with a percent symbol. Supported by: All numeric types.	1 ("P", en-US) -> 100.00 % 1 ("P", fr-FR) -> 100,00 %
"X" or "x"	Hexadecimal	Result: A hexadecimal string. Supported by: Integral types only.	255 ("X") -> FF -1 ("x") -> ff

4.11 Floating-Point Numbers and Type decimal (Cont.)

- The UML class diagram in Fig. 4.20 models class `Account`.

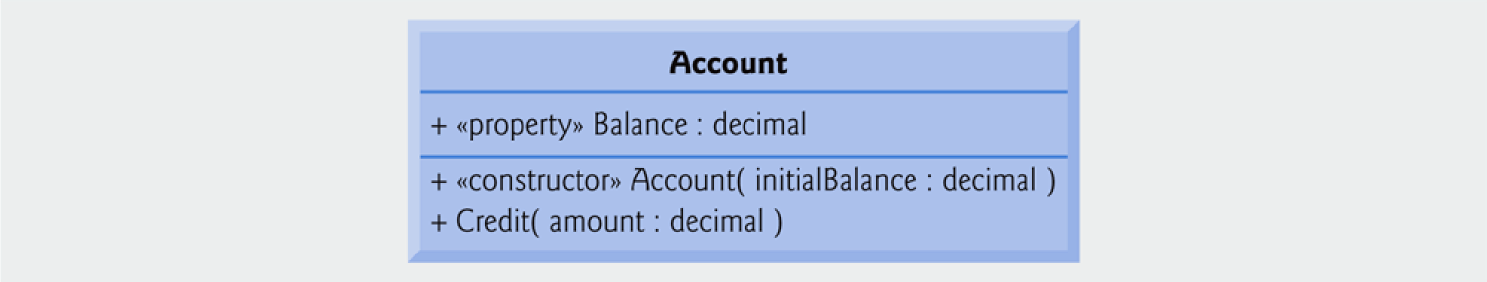
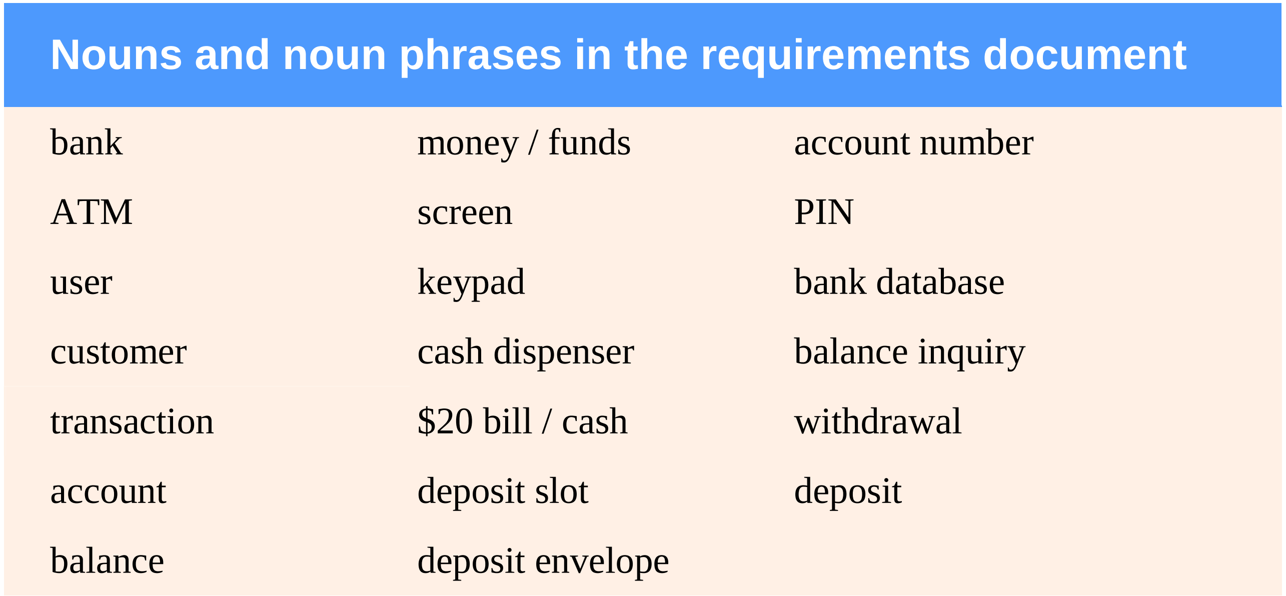

Account
+ «property» Balance : decimal
+ «constructor» Account(initialBalance : decimal)
+ Credit(amount : decimal)

Fig. 4.20 | UML class diagram indicating that class `Account` has a `public Balance` property of type `decimal`, a constructor and a method.

4.12 Software Engineering Case Study: Identifying the Classes in the ATM Requirements Document

- We create classes only for the nouns and noun phrases in the ATM system (Fig. 4.21).
- We do not need to model some nouns such as “bank” which are not part of the ATM operations.



Nouns and noun phrases in the requirements document		
bank	money / funds	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. 4.21 | Nouns and noun phrases in the requirements document.

4.12 Identifying the Classes in the ATM Requirements Document (Cont.)

- UML **class diagrams** model the classes in the ATM system and their interrelationships (Fig. 4.22).
  - The top compartment contains the name of the class.
  - The middle compartment contains the class's attributes.
  - The bottom compartment contains the class's operations.

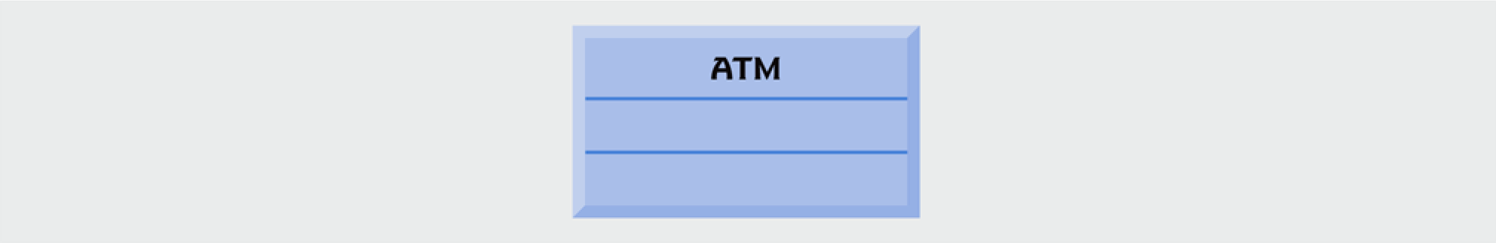


Fig. 4.22 | Representing a class in the UML using a class diagram.

4.12 Identifying the Classes in the ATM Requirements Document (Cont.)

- Figure 4.23 shows how our classes `ATM` and `Withdrawal` relate to one another.
  - The line that connects the two classes represents an **association**.
  - **Multiplicity** values indicate how many objects of each class participate in the association.
  - One `ATM` object participates in an association with either zero or one `Withdrawal` objects.
- `currentTransaction` is a **role name**, which identifies the role the `Withdrawal` object plays.

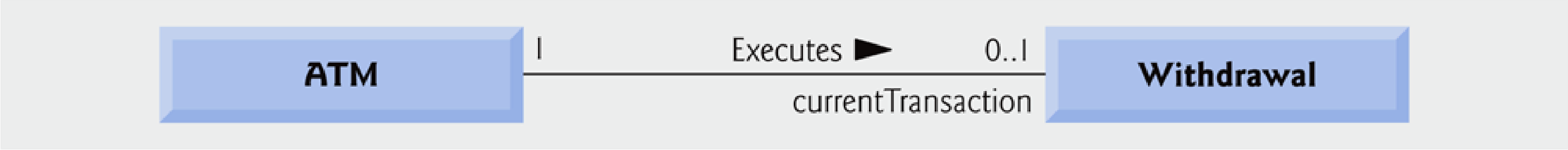


Fig. 4.23 | Class diagram showing an association among classes.

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

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

Fig. 4.24 | Multiplicity types.

4.12 Identifying the Classes in the ATM Requirements Document (Cont.)

- In Fig. 4.25, the **solid diamonds** indicate that class `ATM` has a **composition** relationship with classes `Screen`, `Keypad`, `CashDispenser` and `DepositSlot`.
- Composition implies a whole/part relationship—the ATM “has a” screen, a keypad, a cash dispenser and a deposit slot.
- The **has-a relationship** defines composition.

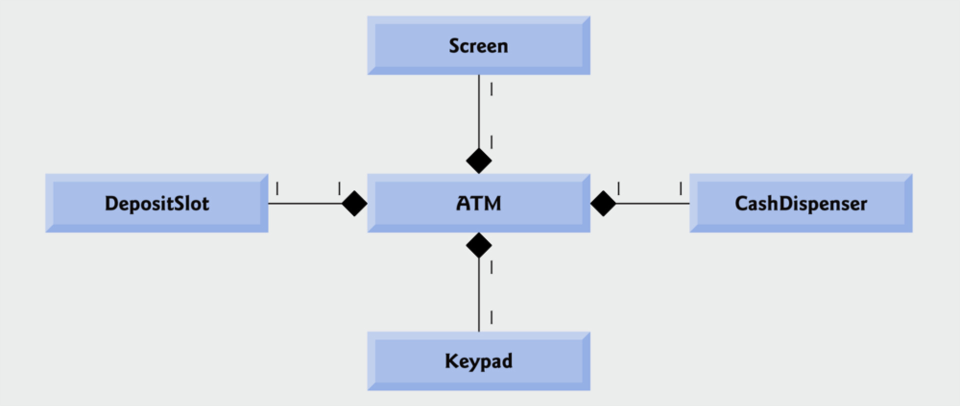


Fig. 4.25 | Class diagram showing composition relationships.

4.12 Identifying the Classes in the ATM Requirements Document (Cont.)

- Composition relationships have the following properties:
  - Only one class in the relationship can represent the whole.
  - The parts in the composition relationship exist only as long as the whole.
  - A part may belong to only one whole at a time.
- If a “has-a” relationship does not satisfy one or more of these criteria, hollow diamonds are used to indicate **aggregation**.

4.12 Identifying the Classes in the ATM Requirements Document (Cont.)

- Figure 4.26 shows a class diagram for the ATM system.
- The class diagram shows that class `ATM` has a **one-to-one relationship** with class `BankDatabase`.
- We also model that one object of class `BankDatabase` participates in a composition relationship with zero or more objects of class `Account`.

4.12 Identifying the Classes in the ATM Requirements Document (Cont.)

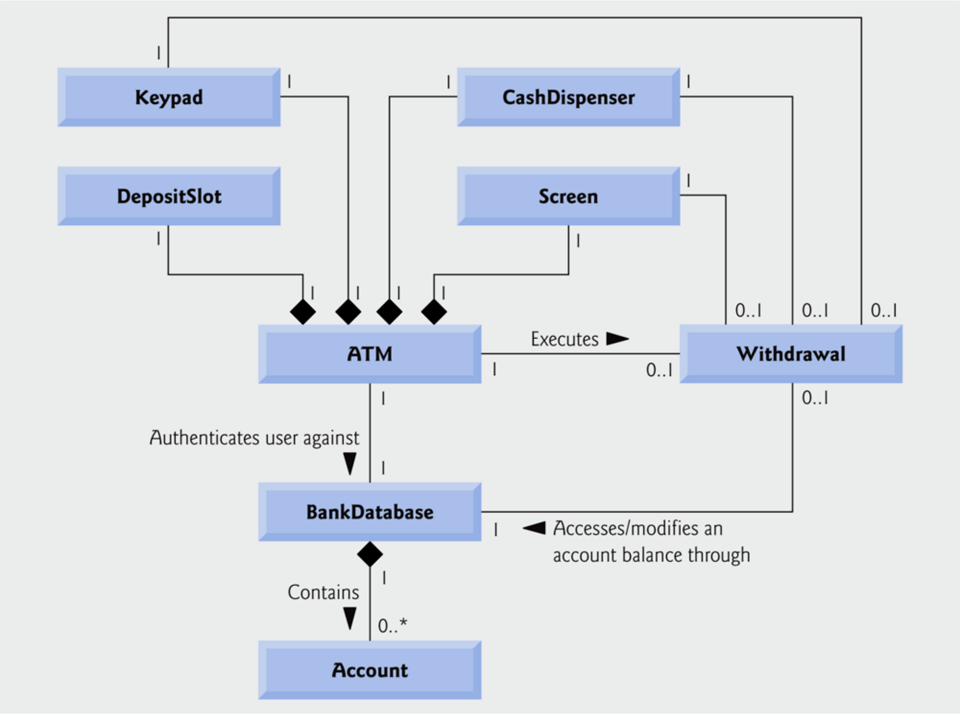


Fig. 4.26 | Class diagram for the ATM system model.