ATM Case Study

OBJECTIVES

....

- ....

2

Requirements

◀ ▶

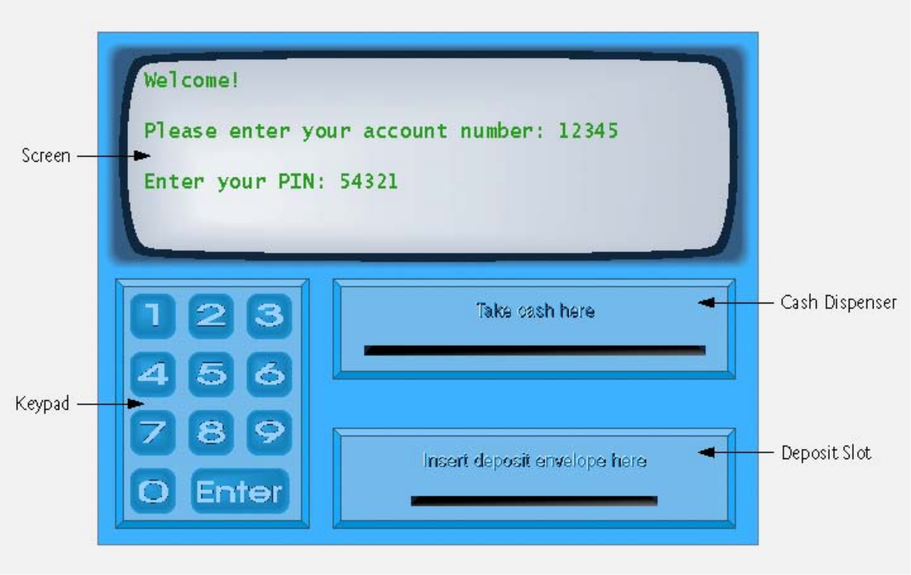
2.9 (Optional) Software Engineering Case Study: Examining the Requirements Document

- Object-oriented design (OOD) process using UML
  - Chapters 3 to 8, 10
- Object-oriented programming (OOP) implementation
  - Appendix J

◀ ▶

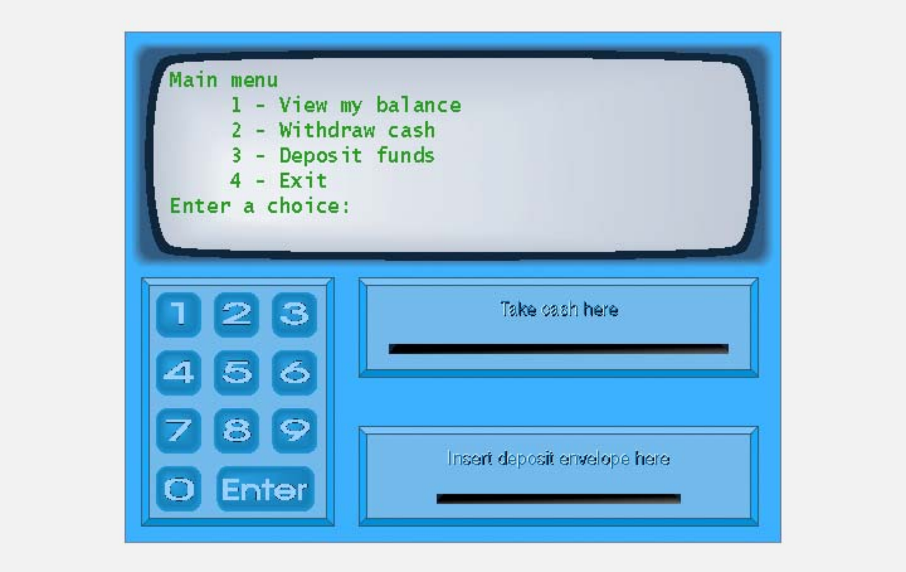
2.9 (Optional) Software Engineering Case Study (Cont.)

- Requirements Document
  - New automated teller machine (ATM)
  - Allows basic financial transaction
    - View balance, withdraw cash, deposit funds
  - User interface
    - Display screen, keypad, cash dispenser, deposit slot
  - ATM session
    - Authenticate user, execute financial transaction



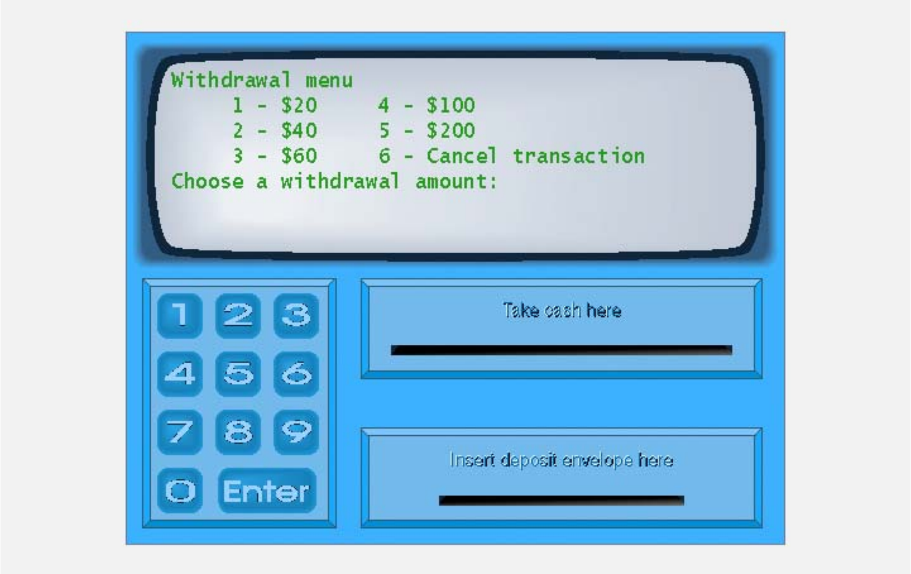
```
Welcome!

Please enter your account number: 12345

Enter your PIN: 54321
```

Fig. 2.17 | Automated teller machine user interface.



```
Main menu
     1 - View my balance
     2 - Withdraw cash
     3 - Deposit funds
     4 - Exit
Enter a choice:
```

Fig. 2.18 | **ATM main menu.**



```
Withdrawal menu
     1 - $20      4 - $100
     2 - $40      5 - $200
     3 - $60      6 - Cancel transaction
Choose a withdrawal amount:
```

Fig. 2.19 | **ATM withdrawal menu.**

2.9 (Optional) Software Engineering Case Study (Cont.)

- Analyzing the ATM System
  - Requirements gathering
  - Software life cycle
    - Waterfall model
    - Interactive model
  - Use case modeling
- Use case Diagram
  - Model the interactions between clients and its use cases
  - Actor
    - External entity

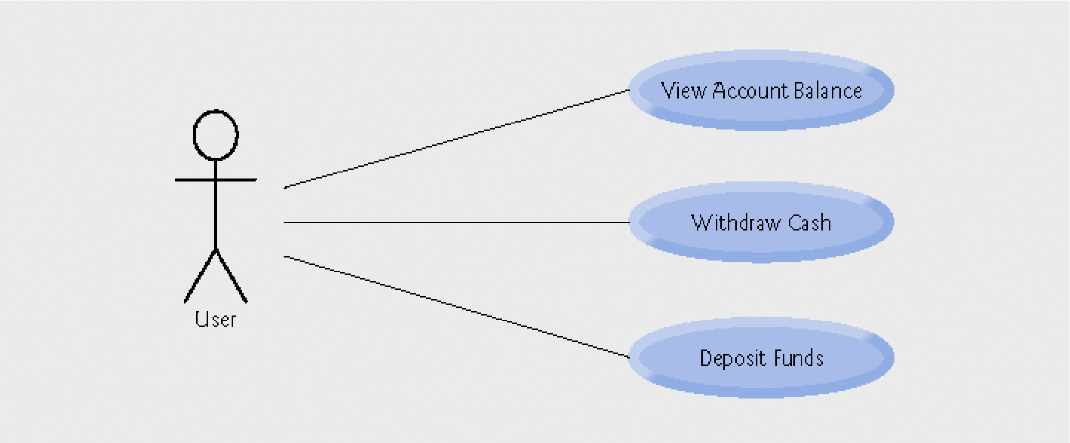


Fig. 2.20 | Use case diagram for the ATM system from the user's perspective.

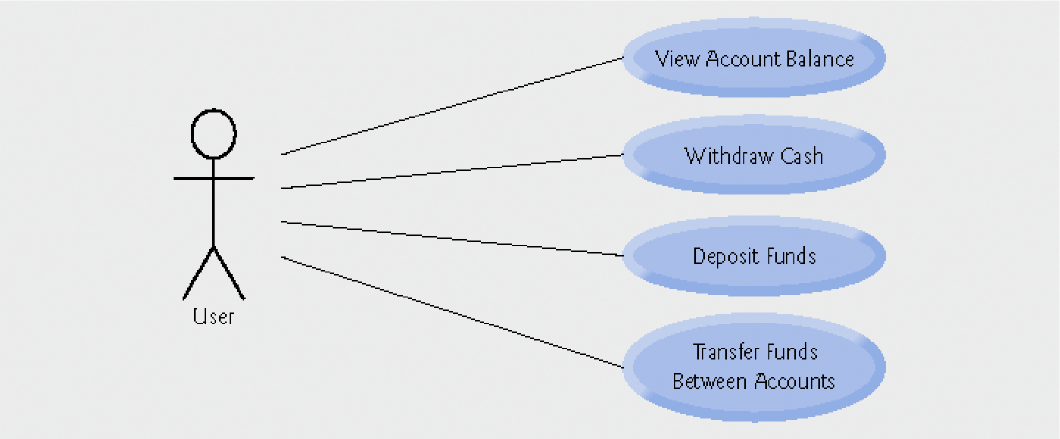


Fig. 2.21 | Use case diagram for a modified version of our ATM system that also allows users to transfer money between accounts.

2.9 (Optional) Software Engineering Case Study (Cont.)

- UML diagram types
  - Model system structure
    - Class diagram
      - Models classes, or “building blocks” of a system
      - screen, keypad, cash dispenser, deposit slot.

2.9 (Optional) Software Engineering Case Study (Cont.)

- Model system behavior
    - Use case diagrams
        - Model interactions between user and a system
    - State machine diagrams
        - Model the ways in which an object changes state
    - Activity diagrams
        - Models an object’s activity during program execution
    - Communication diagrams (collaboration diagrams)
        - Models the interactions among objects
        - Emphasize what interactions occur
    - Sequence diagrams
        - Models the interactions among objects
        - Emphasize when interactions occur

3

Begin Designing the ATM System

3.10 (Optional) Software Engineering Case Study: Identifying the Classes in a Requirements Document

- **Begin designing the ATM system**
  - **Analyze the nouns and noun phrases**
  - **Introduce UML class diagrams**

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 / 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. 3.19 | Nouns and noun phrases in the requirements document.

Modeling Classes

- UML class diagrams
  - Top compartment contains name of the class
  - Middle compartment contains class’s attributes or instance variables
  - Bottom compartment contains class’s operations or methods

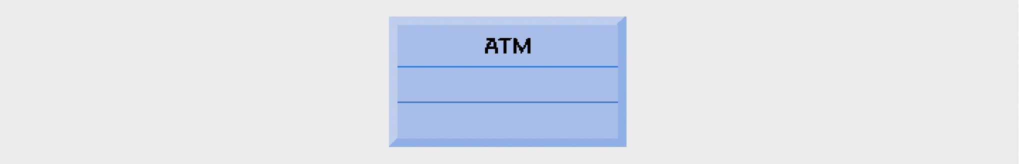


Fig. 3.20 | Representing a class in the UML using a class diagram.

Modeling Classes

- UML class diagrams
  - Allows suppression of class attributes and operations
    - Called an elided diagram
  - Solid line that connects two classes represents an association
    - numbers near end of each line are multiplicity values

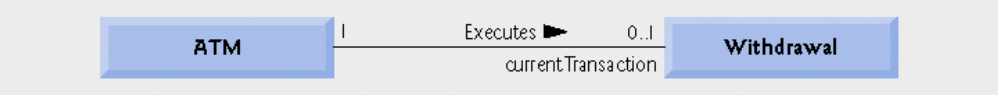


Fig. 3.21 | Class diagram showing an association among classes.

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 non-negative integer (zero or more)**
0..*	**Zero or more (identical to *)**
1..*	**One or more**

Fig. 3.22 | Multiplicity types.

Modeling Classes

- UML class diagrams
  - Solid diamonds attached to association lines indicate a composition relationship
  - Hollow diamonds indicate aggregation – a weaker form of composition

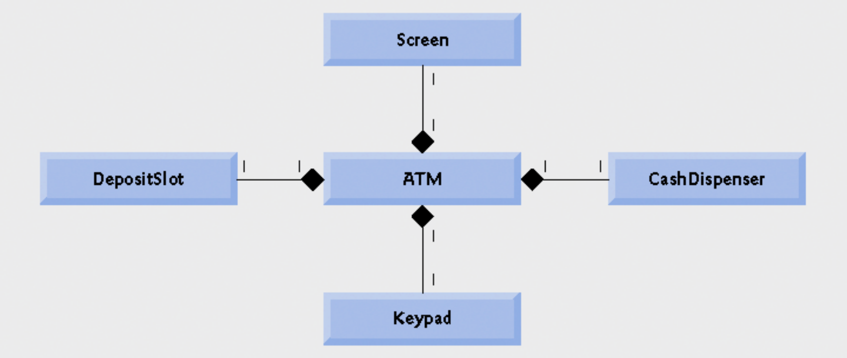


Fig. 3.23 | Class diagram showing composition relationships.

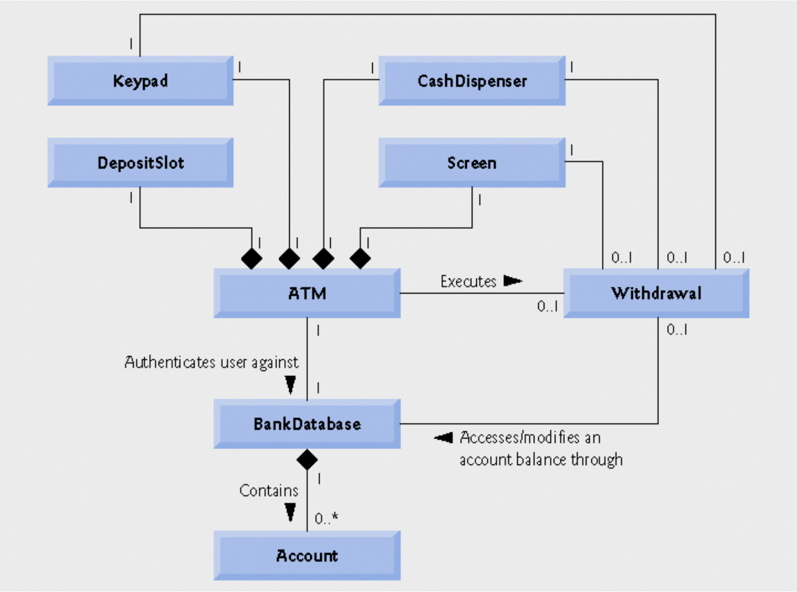


Fig. 3.24 | Class diagram for the ATM system model.

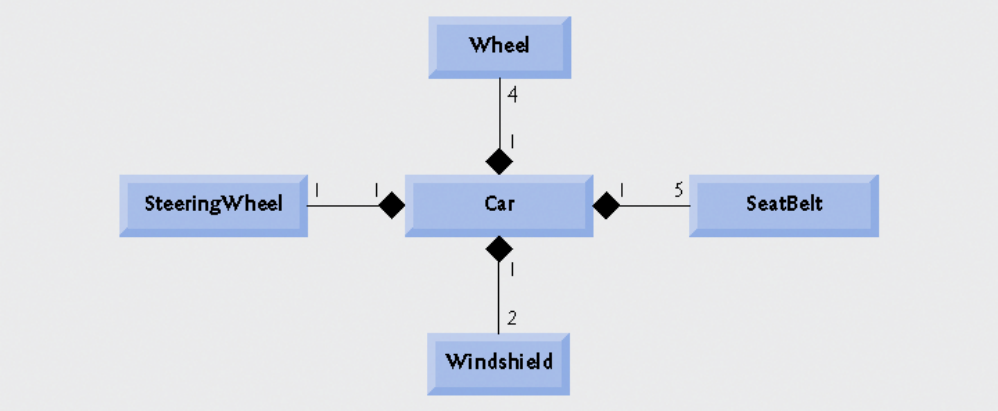


Fig. 3.25 | Class diagram showing composition relationships of a class `Car`.

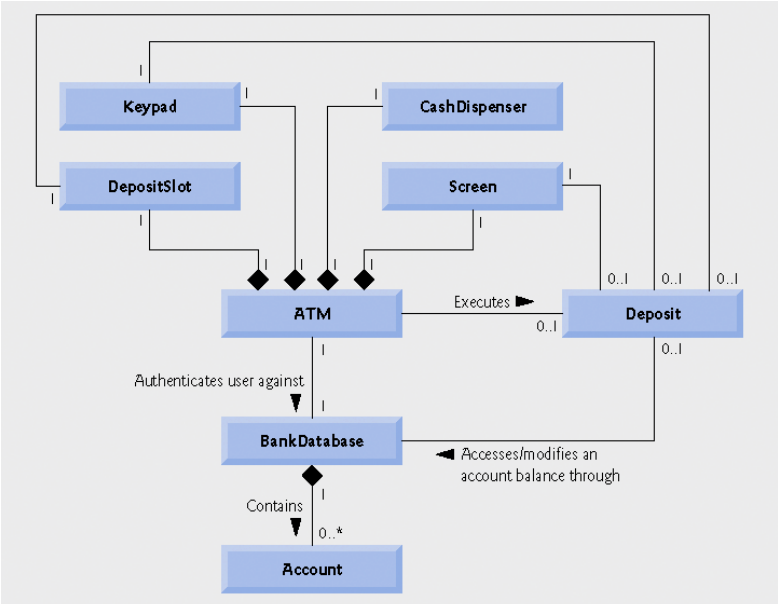


Fig. 3.26 | Class diagram for the ATM system model including class `Deposit`.

4

Identifying Class Attributes

4.15 Identifying Class Attributes

- Identifying attributes
  - Look for descriptive words and phrases in the requirements document
  - Create attributes and assign them to classes
  - Each attribute is given an attribute type
  - Some attributes may have an initial value
  - Some classes may end up without any attributes
    - Additional attributes may be added later on as the design and implementation process continues
  - Reference-type attributes are modeled more clearly as associations

Class	Descriptive words and phrases
`ATM`	user is authenticated
`BalanceInquiry`	account number
`Withdrawal`	account number amount
`Deposit`	account number amount
`BankDatabase`	[no descriptive words or phrases]
`Account`	account number PIN Balance
`Screen`	[no descriptive words or phrases]
`Keypad`	[no descriptive words or phrases]
`CashDispenser`	begins each day loaded with 500 $20 bills
`DepositSlot`	[no descriptive words or phrases]

Fig. 4.23 | Descriptive words and phrases from the ATM requirements.

Software Engineering Observation 4.6

At early stages in the design process, classes often lack attributes (and operations). Such classes should not be eliminated, however, because attributes (and operations) may become evident in the later phases of design and implementation.

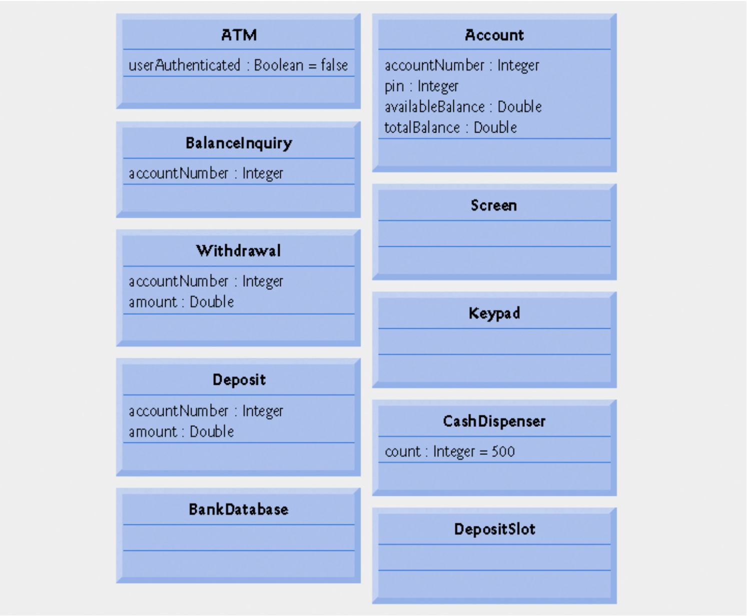


Fig. 4.24 | **Classes with attributes.**

5

Identifying Object’s State and Activities

◀ ▶

5.11 (Optional) Software Engineering Case Study: Identifying Object’s State and Activities

- State Machine Diagrams
  - – Commonly called state diagram
  - – Model several states of an object
  - – Show under what circumstances the object changes state
  - – Focus on system behavior
  - – UML representation
    - State
      - – Rounded rectangle
    - Initial state
      - – Solid circle
    - Transitions
      - – Arrows with stick arrowheads

◀ ▶

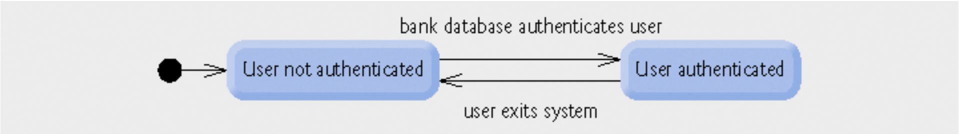


Fig. 5.29 | State diagram for the ATM object.

Software Engineering Observation 5.5

Software designers do not generally create state diagrams showing every possible state and state transition for all attributes—there are simply too many of them. State diagrams typically show only key states and state transitions.

5.11 (Optional) Software Engineering Case Study (Cont.)

- Activity Diagrams
  - Focus on system behavior
  - Model an object’s workflow during program execution
  - Model the actions the object will perform and in what order
  - UML representation
    - Action state (rectangle with its left and right sides replaced by arcs curving outwards)
    - Action order (arrow with a stick arrowhead)
    - Initial state (solid circle)
    - Final state (solid circle enclosed in an open circle)

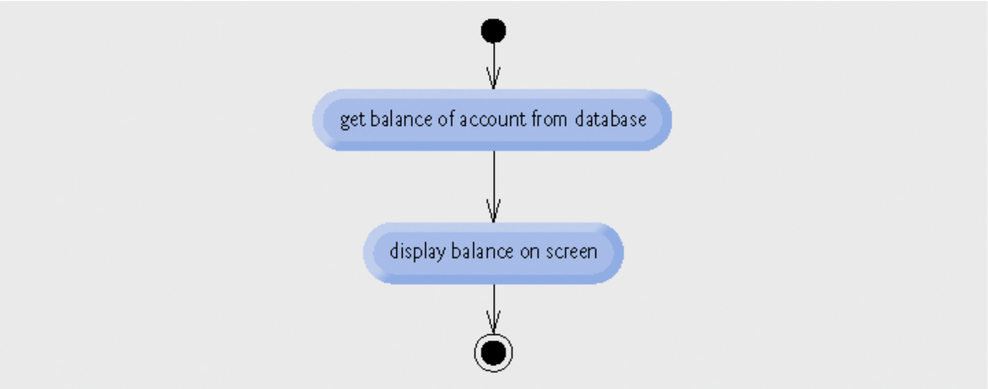

get balance of account from database
display balance on screen

Fig. 5.30 | Activity diagram for a BalanceInquiry object.

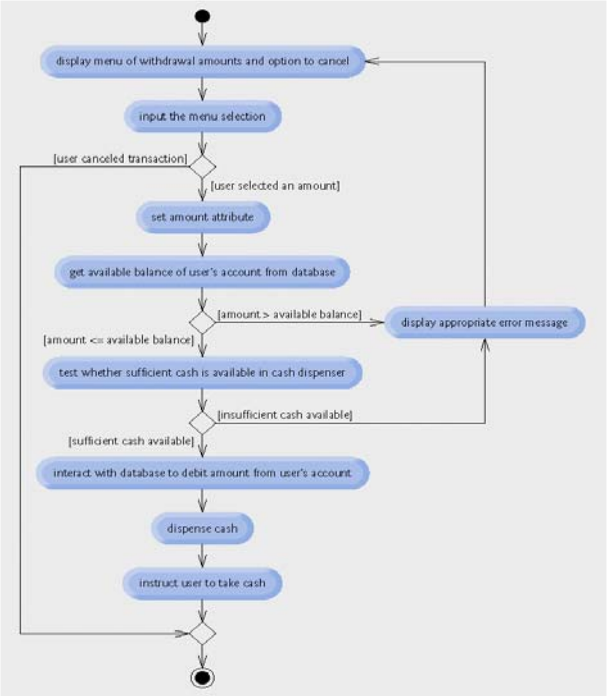

display menu of withdrawal amounts and option to cancel
input the menu selection
[user canceled transaction]
[user selected an amount]
set amount attribute
get available balance of user's account from database
[amount > available balance]
display appropriate error message
[amount <= available balance]
test whether sufficient cash is available in cash dispenser
[insufficient cash available]
[sufficient cash available]
interact with database to debit amount from user's account
dispense cash
instruct user to take cash

Fig. 5.31 | Activity diagram for a withdrawal transaction.

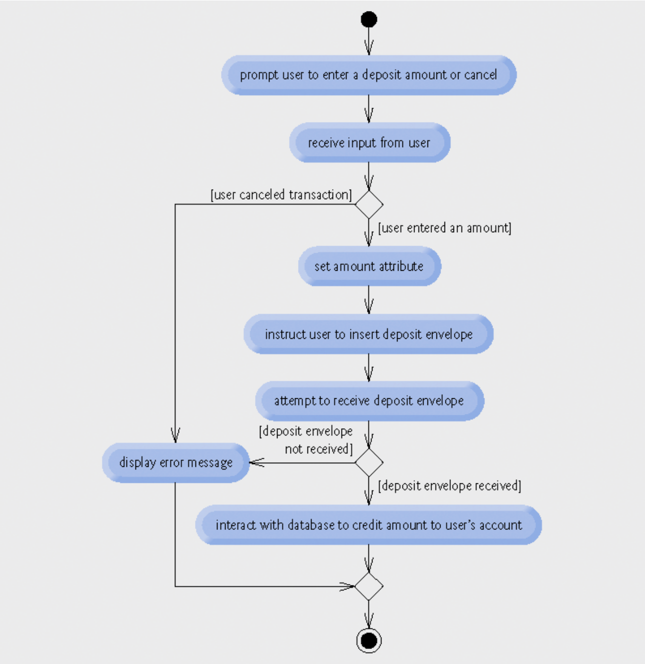

prompt user to enter a deposit amount or cancel
receive input from user
[user canceled transaction]
[user entered an amount]
set amount attribute
instruct user to insert deposit envelope
attempt to receive deposit envelope
[deposit envelope not received]
display error message
[deposit envelope received]
interact with database to credit amount to user's account

Fig. 5.32 | Activity diagram for a deposit transaction.

6

Identifying Class Operations

6.14 (Optional) Identifying Class Operations

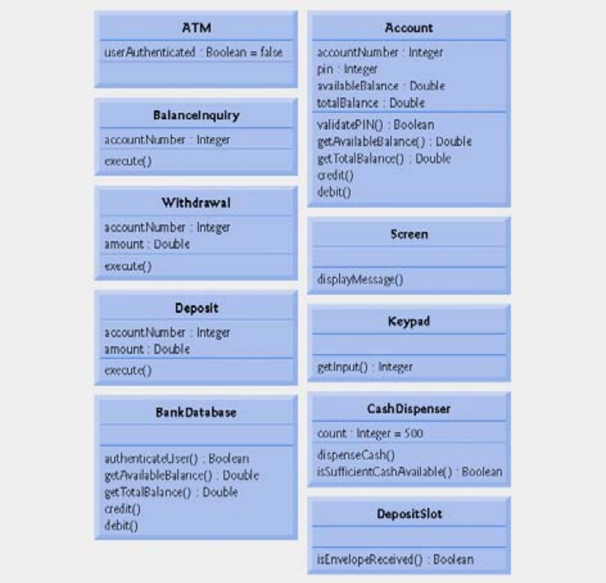
- **Identifying operations**
  - **Examine key verbs and verb phrases in the requirements document**
- **Modeling operations in UML**
  - **Each operation is given an operation name, a parameter list and a return type:**
    - ***operationName*(*parameter1* , *parameter2* , … , *parameterN*) : *return type***
    - **Each parameter has a parameter name and a parameter type**
      - ***parameterName* : *parameterType***

6.14 (Optional) Identifying Class Operations (Cont.)

  - Some operations may not have return types yet
    - Remaining return types will be added as design and implementation proceed
- Identifying and modeling operation parameters
  - Examine what data the operation requires to perform its assigned task
  - Additional parameters may be added later on

Class	Verbs and verb phrases
`ATM`	executes financial transactions
`BalanceInquiry`	[none in the requirements document]
`Withdrawal`	[none in the requirements document]
`Deposit`	[none in the requirements document]
`BankDatabase`	authenticates a user, retrieves an account balance, credits a deposit amount to an account, debits a withdrawal amount from an account
`Account`	retrieves an account balance, credits a deposit amount to an account, debits a withdrawal amount from an account
`Screen`	displays a message to the user
`Keypad`	receives numeric input from the user
`CashDispenser`	dispenses cash, indicates whether it contains enough cash to satisfy a withdrawal request
`DepositSlot`	receives a deposit envelope

Fig. 6.20 | **Verbs and verb phrases for each class in the ATM system.**



ATM
userAuthenticated : Boolean = false

BalanceInquiry
accountNumber : Integer
execute()

Withdrawal
accountNumber : Integer
amount : Double
execute()

Deposit
accountNumber : Integer
amount : Double
execute()

BankDatabase
authenticateUser() : Boolean
getAvailableBalance() : Double
getTotalBalance() : Double
credit()
debit()

Account
accountNumber : Integer
pin : Integer
availableBalance : Double
totalBalance : Double
validatePIN() : Boolean
getAvailableBalance() : Double
getTotalBalance() : Double
credit()
debit()

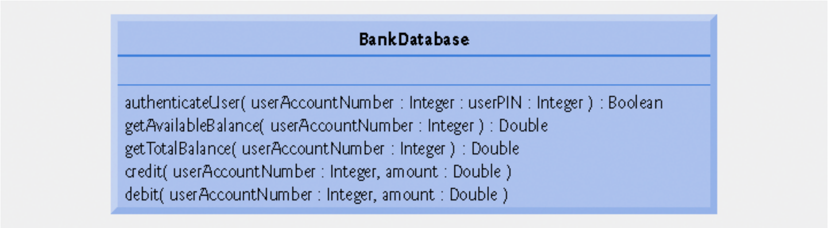
Screen
displayMessage()

Keypad
getInput() : Integer

CashDispenser
count : Integer = 500
dispenseCash()
isSufficientCashAvailable() : Boolean

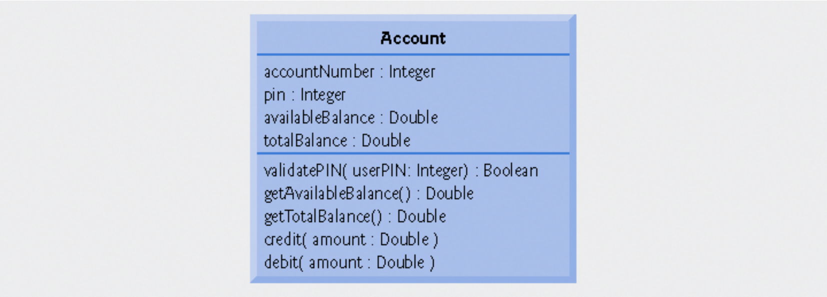
DepositSlot
isEnvelopeReceived() : Boolean

Fig. 6.21 | **Classes in the ATM system with attributes and operations.**



BankDatabase
authenticateUser(userAccountNumber : Integer : userPIN : Integer) : Boolean
getAvailableBalance(userAccountNumber : Integer) : Double
getTotalBalance(userAccountNumber : Integer) : Double
credit(userAccountNumber : Integer, amount : Double)
debit(userAccountNumber : Integer, amount : Double)

Fig. 6.22 | **Class `BankDatabase` with operation parameters.**

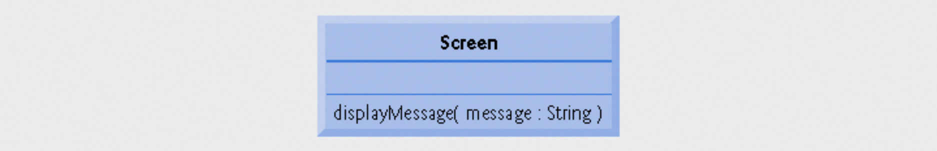


Account

accountNumber : Integer
pin : Integer
availableBalance : Double
totalBalance : Double

validatePIN(userPIN: Integer) : Boolean
getAvailableBalance() : Double
getTotalBalance() : Double
credit(amount : Double)
debit(amount : Double)

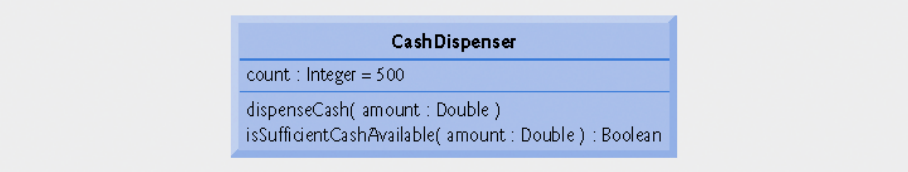
Fig. 6.23 | **Class `Account` with operation parameters.**



Screen

displayMessage(message : String)

Fig. 6.24 | **Class `Screen` with operation parameters.**



CashDispenser

count : Integer = 500

dispenseCash(amount : Double)
isSufficientCashAvailable(amount : Double) : Boolean

Fig. 6.25 | Class `CashDispenser` with operation parameters.

7

Collaboration Among Objects

7.14 (Optional) Software Engineering Case Study: Collaboration Among Objects

- Collaborations
  - When objects communicate to accomplish task
    - Accomplished by invoking operations (methods)
  - One object sends a message to another object

7.14 (Optional) Software Engineering Case Study (Cont.)

- Identifying the collaborations in a system
  - Read requirements document to find
    - What ATM should do to authenticate a use
    - What ATM should do to perform transactions
  - For each action, decide
    - Which objects must interact
      - Sending object
      - Receiving object

An object of class…	sends the message…	to an object of class…
ATM	displayMessage	Screen
	getInput	Keypad
	authenticateUser	BankDatabase
	execute	BalanceInquiry
	execute	Withdrawal
	Execute	Deposit
BalanceInquiry	getAvailableBalance	BankDatabase
	getTotalBalance	BankDatabase
	displayMessage	Screen
Withdrawal	displayMessage	Screen
	getInput	Keypad
	getAvailableBalance	BankDatabase
	isSufficientCashAvailable	CashDispenser
	debit	BankDatabase
	dispenseCash	CashDispenser
Deposit	displayMessage	Screen
	getInput	Keypad
	isEnvelopeReceived	DepositSlot
	Credit	BankDatabase
BankDatabase	validatePIN	Account
	getAvailableBalance	Account
	getTotalBalance	Account
	debit	Account
	Credit	Account

Fig. 7.25 | Collaborations in the ATM system.

7.14 (Optional) Software Engineering Case Study (Cont.)

- Interaction Diagrams
  - Model interactions use UML
  - Communication diagrams
    - Also called collaboration diagrams
    - Emphasize which objects participate in collaborations
  - Sequence diagrams
    - Emphasize when messages are sent between objects

7.14 (Optional) Software Engineering Case Study (Cont.)

- Communication diagrams
  - Objects
    - Modeled as rectangles
    - Contain names in the form `objectName : className`
  - Objects are connected with solid lines
  - Messages are passed alone these lines in the direction shown by arrows
  - Name of message appears next to the arrow

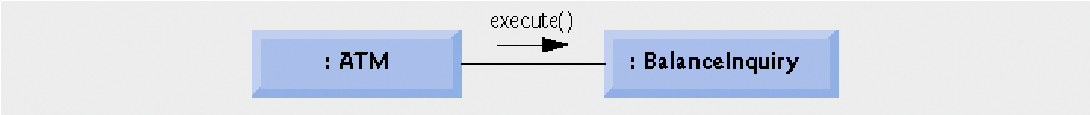


Fig. 7.26 | Communication diagram of the ATM executing a balance inquiry.

7.14 (Optional) Software Engineering Case Study (Cont.)

- Sequence of messages in a communication diagram
  - Appear to the left of a message name
  - Indicate the order in which the message is passed
  - Process in numerical order from least to greatest

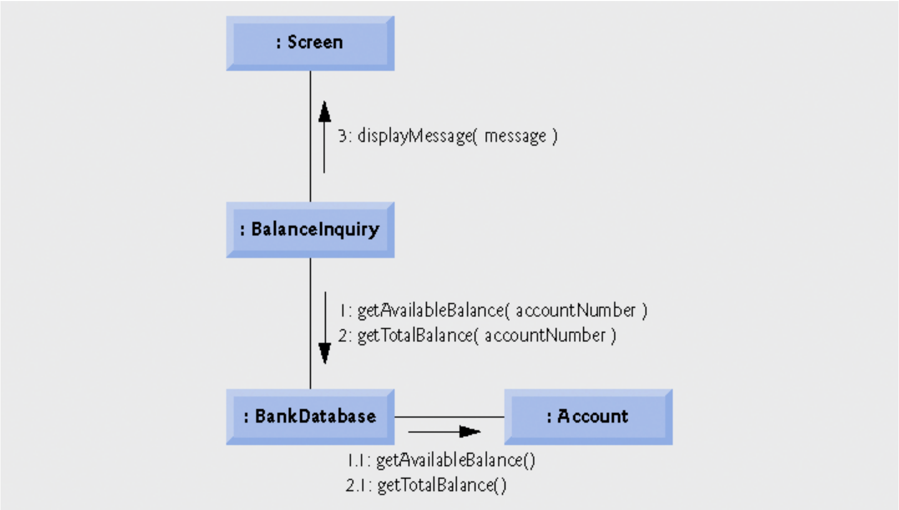

: Screen
3: displayMessage(message)
: BalanceInquiry
1: getAvailableBalance(accountNumber)
2: getTotalBalance(accountNumber)
: BankDatabase
: Account
1.1: getAvailableBalance()
2.1: getTotalBalance()

Fig. 7.27 | Communication diagram for executing a balance inquiry.

7.14 (Optional) Software Engineering Case Study (Cont.)

- Sequence diagrams
  - Help model the timing of collaborations
  - Lifeline
    - Dotted line extending down from an object's rectangle
      - Represents the progression of time
  - Activation
    - Thin vertical rectangle
      - Indicates that an object is executing

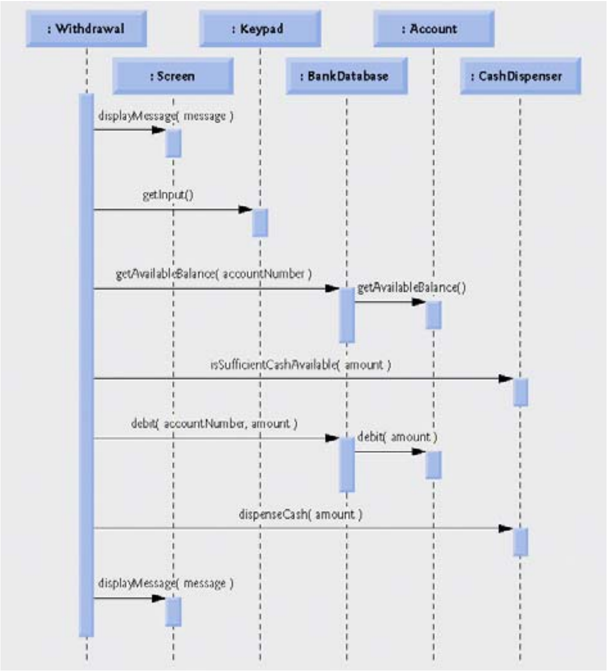

: Withdrawal
: Keypad
: Account
: Screen
: BankDatabase
: CashDispenser
displayMessage(message)
getInput()
getAvailableBalance(accountNumber)
getAvailableBalance()
isSufficientCashAvailable(amount)
debit(accountNumber, amount)
debit(amount)
dispenseCash(amount)
displayMessage(message)

Fig. 7.28 | Sequence diagram that models a `Withdrawal` executing.

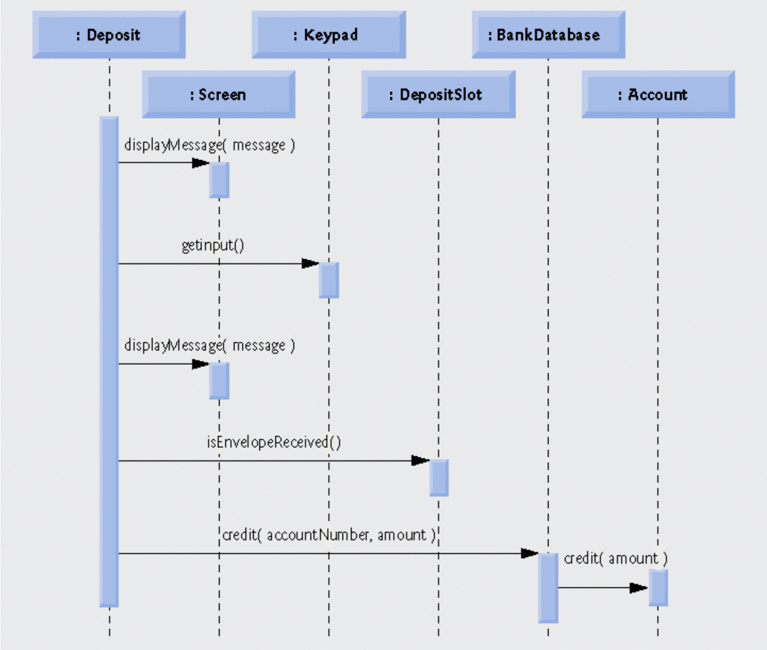


Fig. 7.29 | Sequence diagram that models a `Deposit` executing.

8

Starting to Program the Classes of the ATM System

8.18 (Optional) GUI and Graphics Case Study: Using Objects with Graphics

- **To create a consistent drawing that remains the same each time it is drawn**
  - **Store information about the displayed shapes so that they can be reproduced exactly the same way each time `paintComponent` is called**

8.19 Starting to Program the Classes of the ATM System

- **Visibility**
  - **Attributes normally should be private, methods invoked by clients should be public**
  - **Visibility markers in UML**
    - **A plus sign (+) indicates public visibility**
    - **A minus sign (-) indicates private visibility**
- **Navigability**
  - **Navigability arrows indicate in which direction an association can be traversed**
  - **Bidirectional navigability**
    - **Associations with navigability arrows at both ends or no navigability arrows at all can be traversed in either direction**

8.19 Starting to Program the Classes of the ATM System (Cont.)

- Implementing the ATM system from its UML design (for each class)
  - Declare a `public` class with the name in the first compartment and an empty no-argument constructor
  - Declare instance variables based on attributes in the second compartment
  - Declare references to other objects based on associations described in the class diagram
  - Declare the shells of the methods based on the operations in the third compartment
    - Use the return type `void` if no return type has been specified

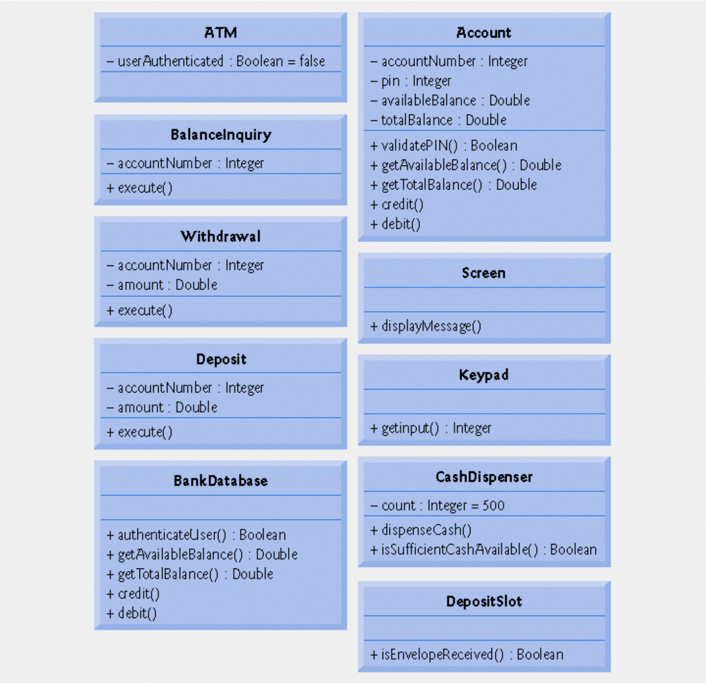

ATM
– userAuthenticated : Boolean = false
BalanceInquiry
– accountNumber : Integer
+ execute()
Withdrawal
– accountNumber : Integer
– amount : Double
+ execute()
Deposit
– accountNumber : Integer
– amount : Double
+ execute()
BankDatabase
+ authenticateUser() : Boolean
+ getAvailableBalance() : Double
+ getTotalBalance() : Double
+ credit()
+ debit()
Account
– accountNumber : Integer
– pin : Integer
– availableBalance : Double
– totalBalance : Double
+ validatePIN() : Boolean
+ getAvailableBalance() : Double
+ getTotalBalance() : Double
+ credit()
+ debit()
Screen
+ displayMessage()
Keypad
+ getinput() : Integer
CashDispenser
– count : Integer = 500
+ dispenseCash()
+ isSufficientCashAvailable() : Boolean
DepositSlot
+ isEnvelopeReceived() : Boolean

Fig. 8.24 | Class diagram with visibility markers.

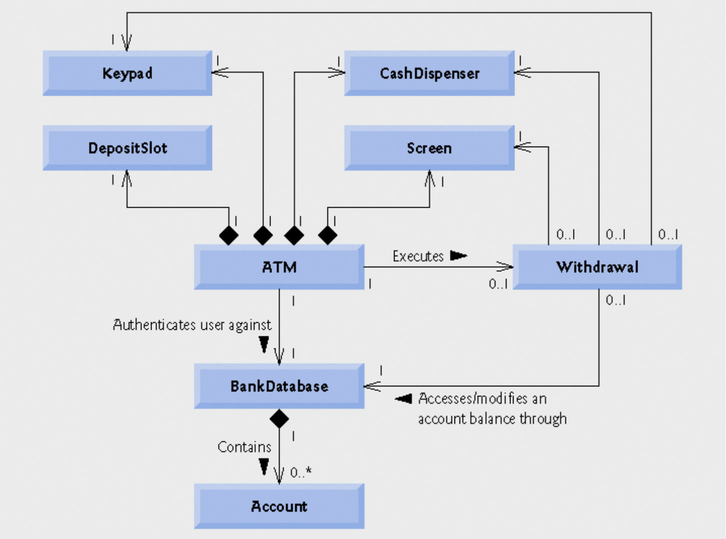


Fig. 8.25 | Class diagram with navigability arrows.

Outline

```
// Class Withdrawal represents an ATM withdrawal transaction
public class Withdrawal
{
   // no-argument constructor
   public Withdrawal()
   {
   } // end no-argument Withdrawal constructor
} // end class Withdrawal
```

Class for **`Withdrawal`**

Empty no-argument constructor

`withdrawal.java`

Outline

withdrawal.java

```java
// Class Withdrawal represents an ATM withdrawal transaction
public class Withdrawal
{
   // attributes
   private int accountNumber; // account to withdraw funds from
   private double amount; // amount to withdraw

   // no-argument constructor
   public Withdrawal()
   {
   } // end no-argument Withdrawal constructor
} // end class Withdrawal
```

Declare instance variables

Outline

withdrawal.java

```java
// Class Withdrawal represents an ATM withdrawal transaction
public class Withdrawal
{
   // attributes
   private int accountNumber; // account to withdraw funds from
   private double amount; // amount to withdraw

   // references to associated objects
   private Screen screen; // ATM’s screen
   private Keypad keypad; // ATM’s keypad
   private CashDispenser cashDispenser; // ATM’s cash dispenser
   private BankDatabase bankDatabase; // account info database

   // no-argument constructor
   public Withdrawal()
   {
   } // end no-argument Withdrawal constructor
} // end class Withdrawal
```

Declare references to other objects

Outline

```java
// Class Withdrawal represents an ATM withdrawal transaction
public class Withdrawal
{
   // attributes
   private int accountNumber; // account to withdraw funds from
   private double amount; // amount to withdraw

   // references to associated objects
   private Screen screen; // ATM’s screen
   private Keypad keypad; // ATM’s keypad
   private CashDispenser cashDispenser; // ATM’s cash dispenser
   private BankDatabase bankDatabase; // account info database

   // no-argument constructor
   public Withdrawal()
   {
   } // end no-argument Withdrawal constructor

   // operations
   public void execute()
   {
   } // end method execute
} // end class Withdrawal
```

withdrawal.java

Declare shell of a method with return type void

Outline

```java
// Class Keypad represents an ATM’s keypad
public class Keypad
{
   // no attributes have been specified yet

   // no-argument constructor
   public Keypad()
   {
   } // end no-argument Keypad constructor

   // operations
   public int getInput()
   {
   } // end method getInput
} // end class Keypad
```

withdrawal.java

10

Incorporating Inheritance into the ATM System

10.9 (Optional) Software Engineering Case Study: Incorporating Inheritance into the ATM System

- UML model for inheritance
  - The generalization relationship
    - The superclass is a generalization of the subclasses
    - The subclasses are specializations of the superclass
- `Transaction` superclass
  - Contains the methods and fields `BalanceInquiry`, `Withdrawal` and `Deposit` have in common
    - `execute` method
    - `accountNumber` field

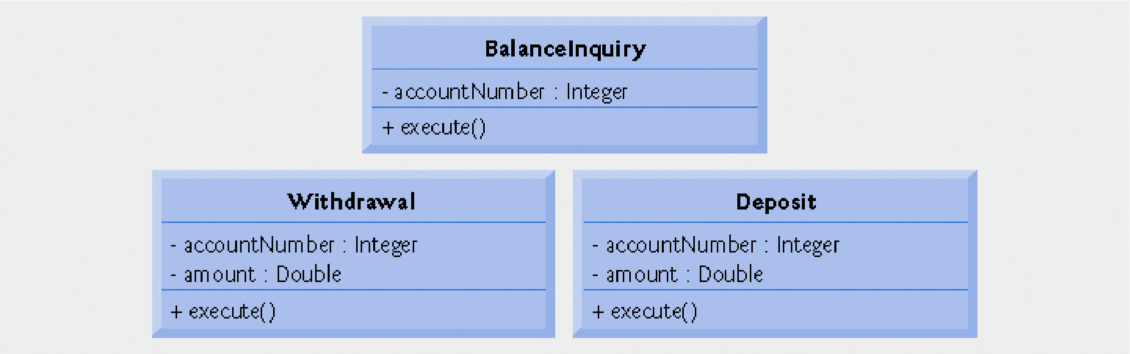


Fig. 10.19 | **Attributes and operations of classes `BalanceInquiry`, `Withdrawal` and `Deposit`.**

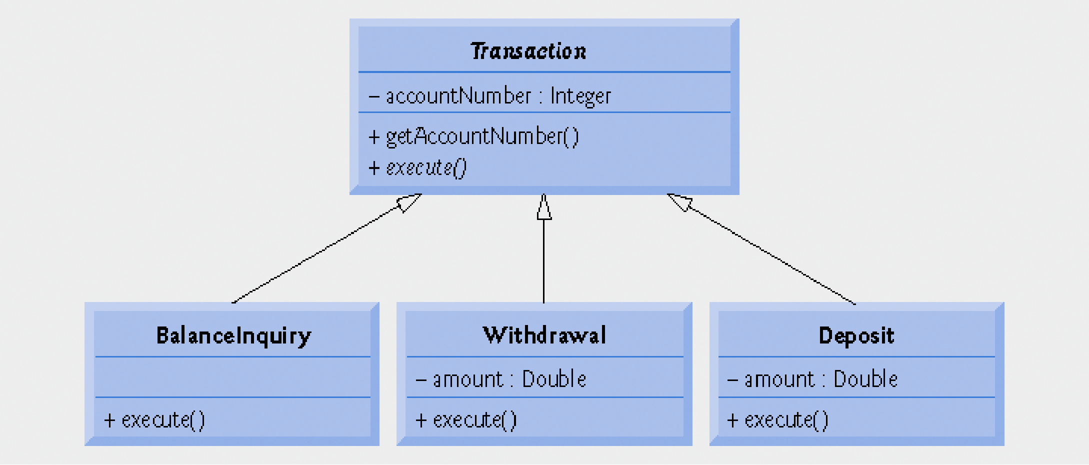


Fig. 10. 20 | **Class diagram modeling generalization of superclass `Transaction` and subclasses `BalanceInquiry`, `Withdrawal` and `Deposit`. Note that abstract class names (e.g., `Transaction`) and method names (e.g., `execute` in class `Transaction`) appear in italics.**

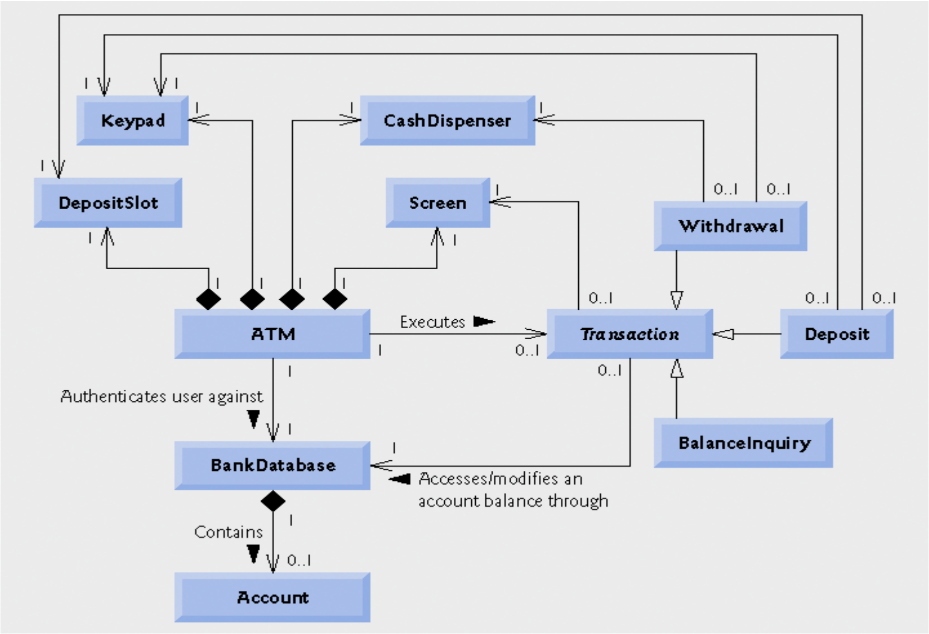


Fig. 10.21 | **Class diagram of the ATM system (incorporating inheritance). Note that abstract class names (e.g., `Transaction`) appear in italics.**

Software Engineering Observation 10.12

A complete class diagram shows all the associations among classes and all the attributes and operations for each class. When the number of class attributes, methods and associations is substantial (as in Fig. 10.21 and Fig. 10.22), a good practice that promotes readability is to divide this information between two class diagrams—one focusing on associations and the other on attributes and methods.

10.9 (Optional) Software Engineering Case Study: Incorporating Inheritance into the ATM System (Cont.)

- Incorporating inheritance into the ATM system design
  - If class **A** is a generalization of class **B**, then class **B** extends class **A**
  - If class **A** is an abstract class and class **B** is a subclass of class **A**, then class **B** must implement the abstract methods of class **A** if class **B** is to be a concrete class

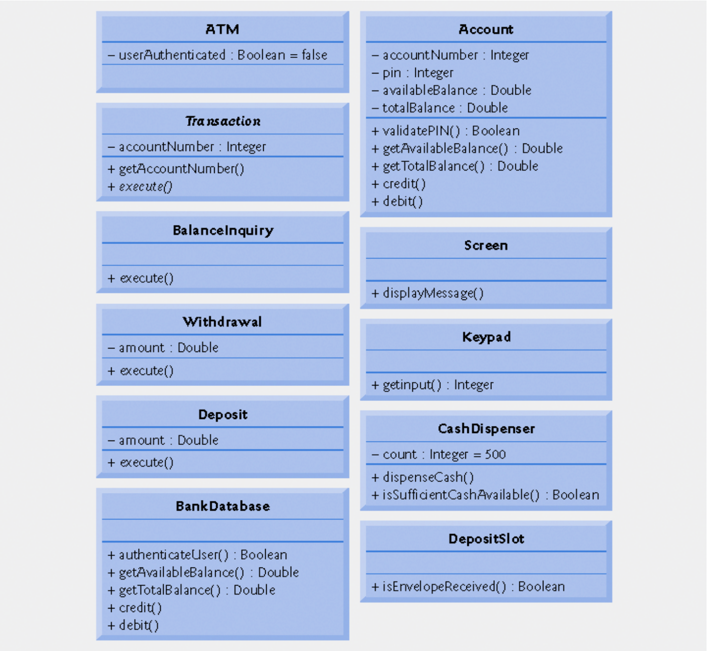

ATM
– userAuthenticated : Boolean = false
Transaction
– accountNumber : Integer
+ getAccountNumber()
+ *execute()*
BalanceInquiry
+ execute()
Withdrawal
– amount : Double
+ execute()
Deposit
– amount : Double
+ execute()
BankDatabase
+ authenticateUser() : Boolean
+ getAvailableBalance() : Double
+ getTotalBalance() : Double
+ credit()
+ debit()
Account
– accountNumber : Integer
– pin : Integer
– availableBalance : Double
– totalBalance : Double
+ validatePIN() : Boolean
+ getAvailableBalance() : Double
+ getTotalBalance() : Double
+ credit()
+ debit()
Screen
+ displayMessage()
Keypad
+ getInput() : Integer
CashDispenser
– count : Integer = 500
+ dispenseCash()
+ isSufficientCashAvailable() : Boolean
DepositSlot
+ isEnvelopeReceived() : Boolean

Fig. 10.22 | Class diagram with attributes and operations (incorporating inheritance). Note that abstract class names (e.g., `Transaction`) and method names (e.g., `execute` in class `Transaction`) appear in italic

Outline

Withdrawal.java

```java
// Class Withdrawal represents an ATM withdrawal transaction
public class Withdrawal extends Transaction
{
} // end class Withdrawal
```

Subclass **Withdrawal** extends superclass **Transaction**

Outline

Withdrawal.java

```java
// Withdrawal.java
// Generated using the class diagrams in Fig. 10.21 and Fig. 10.22
public class Withdrawal extends Transaction
{
   // attributes
   private double amount; // amount to withdraw
   private Keypad keypad; // reference to keypad
   private CashDispenser cashDispenser; // reference to cash dispenser

   // no-argument constructor
   public Withdrawal()
   {
   } // end no-argument Withdrawal constructor

   // method overriding execute
   public void execute()
   {
   } // end method execute
} // end class Withdrawal
```

Subclass **Withdrawal** extends superclass **Transaction**

Software Engineering Observation 10.13

Several UML modeling tools convert UML-based designs into Java code and can speed the implementation process considerably. For more information on these tools, refer to the Internet and Web Resources listed at the end of Section 2.9.

Outline

```java
// Abstract class Transaction represents an ATM transaction
public abstract class Transaction
{
   // attributes
   private int accountNumber; // indicates account involved
   private Screen screen; // ATM’s screen
   private BankDatabase bankDatabase; // account info database

   // no-argument constructor invoked by subclasses using super()
   public Transaction()
   {
   } // end no-argument Transaction constructor

   // return account number
   public int getAccountNumber()
   {
   } // end method getAccountNumber

```

Declare **`abstract`** superclass **`Transaction`**

`Transaction.java`

(1 of 2)

Outline

```
   // return reference to screen
   public Screen getScreen()
   {
   } // end method getScreen

   // return reference to bank database
   public BankDatabase getBankDatabase()
   {
   } // end method getBankDatabase

   // abstract method overridden by subclasses
   public abstract void execute();
} // end class Transaction
```

Declare **`abstract`** method **`execute`**

`Transaction.java`

(2 of 2)