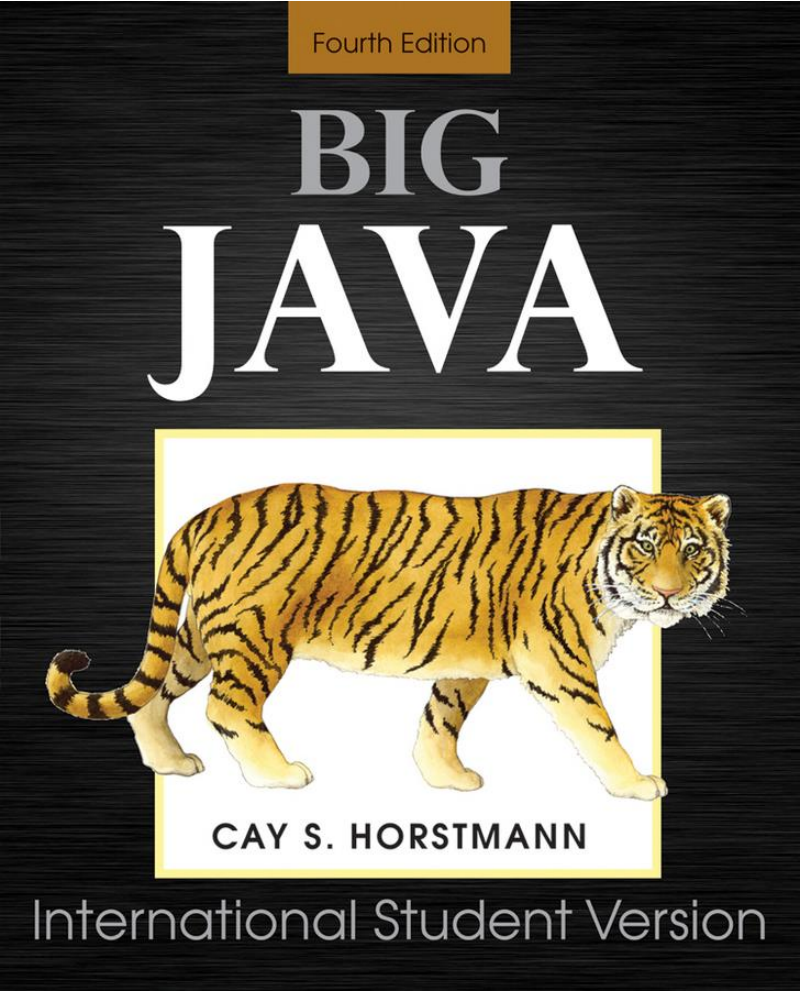


Chapter 11 – Object-Oriented Design

Chapter Goals

- To learn about the software life cycle
- To learn how to discover new classes and methods
- To understand the use of CRC cards for class discovery
- To be able to identify inheritance, aggregation, and dependency relationships between classes
- To master the use of UML class diagrams to describe class relationships
- To learn how to use object-oriented design to build complex programs

The Software Life Cycle

- Encompasses all activities from initial analysis until obsolescence
- Formal process for software development
  - *Describes phases of the development process*
  - *Gives guidelines for how to carry out the phases*
- Development process
  - *Analysis*
  - *Design*
  - *Implementation*
  - *Testing*
  - *Deployment*

Analysis

- Decide what the project is supposed to do
- Do not think about how the program will accomplish tasks
- Output: Requirements document
  - *Describes what program will do once completed*
  - *User manual: Tells how user will operate program*
  - *Performance criteria*

Design

- Plan how to implement the system
- Discover structures that underlie problem to be solved
- Decide what classes and methods you need
- Output:
  - *Description of classes and methods*
  - *Diagrams showing the relationships among the classes*

Implementation

- Write and compile the code
- Code implements classes and methods discovered in the design phase
- Program Run: Completed program

Testing

- Run tests to verify the program works correctly
- Program Run: A report of the tests and their results

Deployment

- Users install program
- Users use program for its intended purpose

The Waterfall Model

- Sequential process of analysis, design, implementation, testing, and deployment
- When rigidly applied, waterfall model did not work

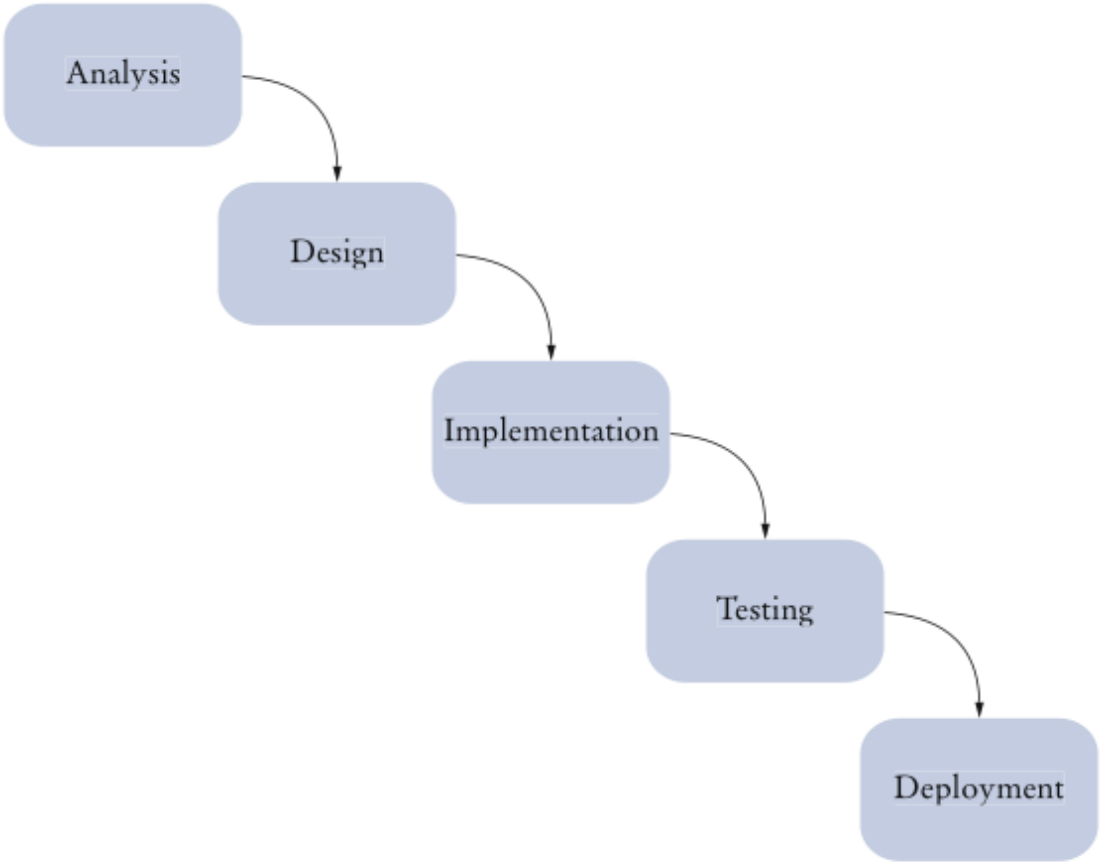


Figure 1 The Waterfall Model

The Spiral Model

- Breaks development process down into multiple phases
- Early phases focus on the construction of *prototypes*
- Lessons learned from development of one prototype can be applied to the next iteration

The Spiral Model

- Problem: Can lead to many iterations, and process can take too long to complete

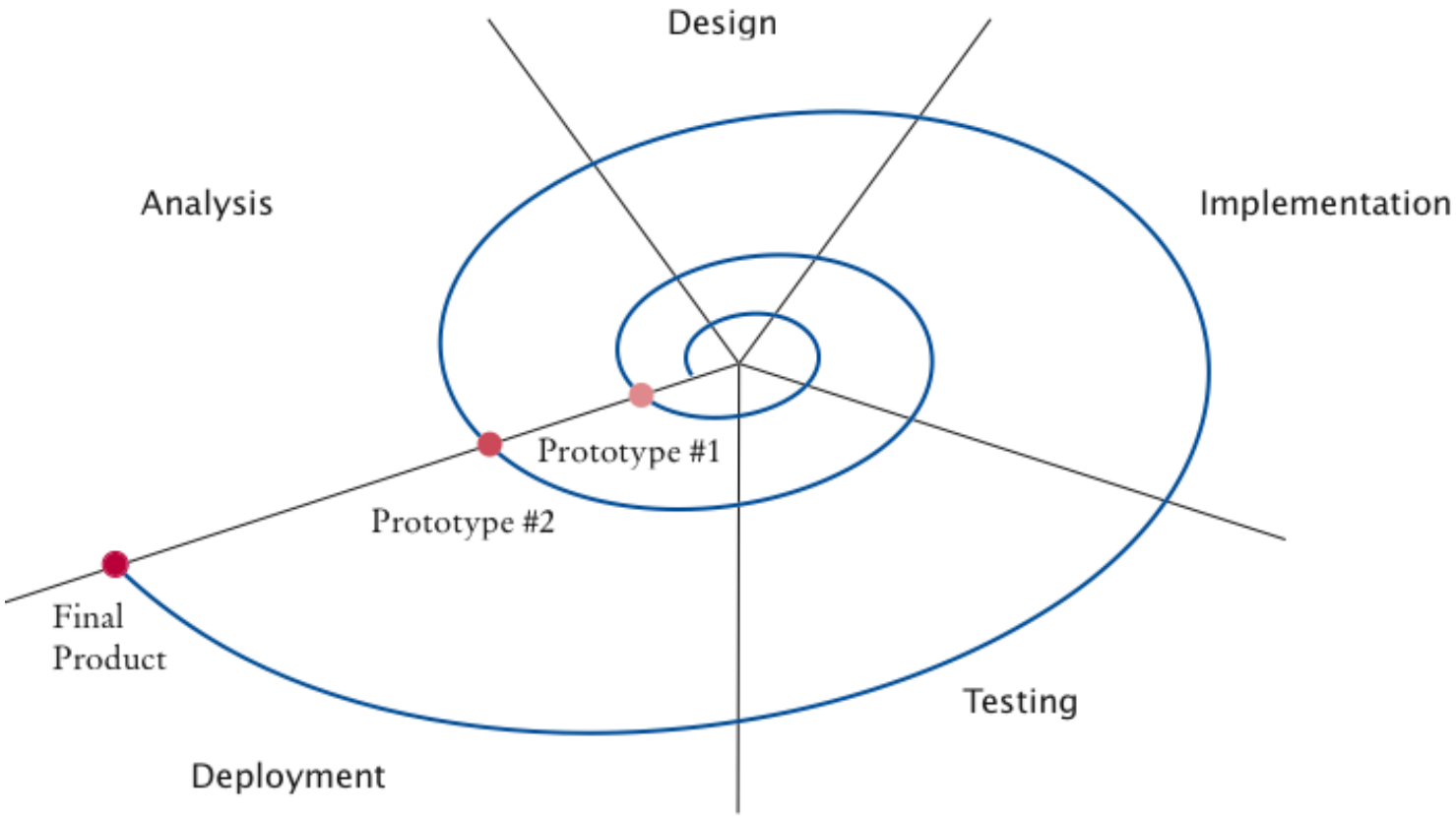


Figure 2 A Spiral Model

Activity Levels in the Rational Unified Process

Development process methodology by the inventors of UML

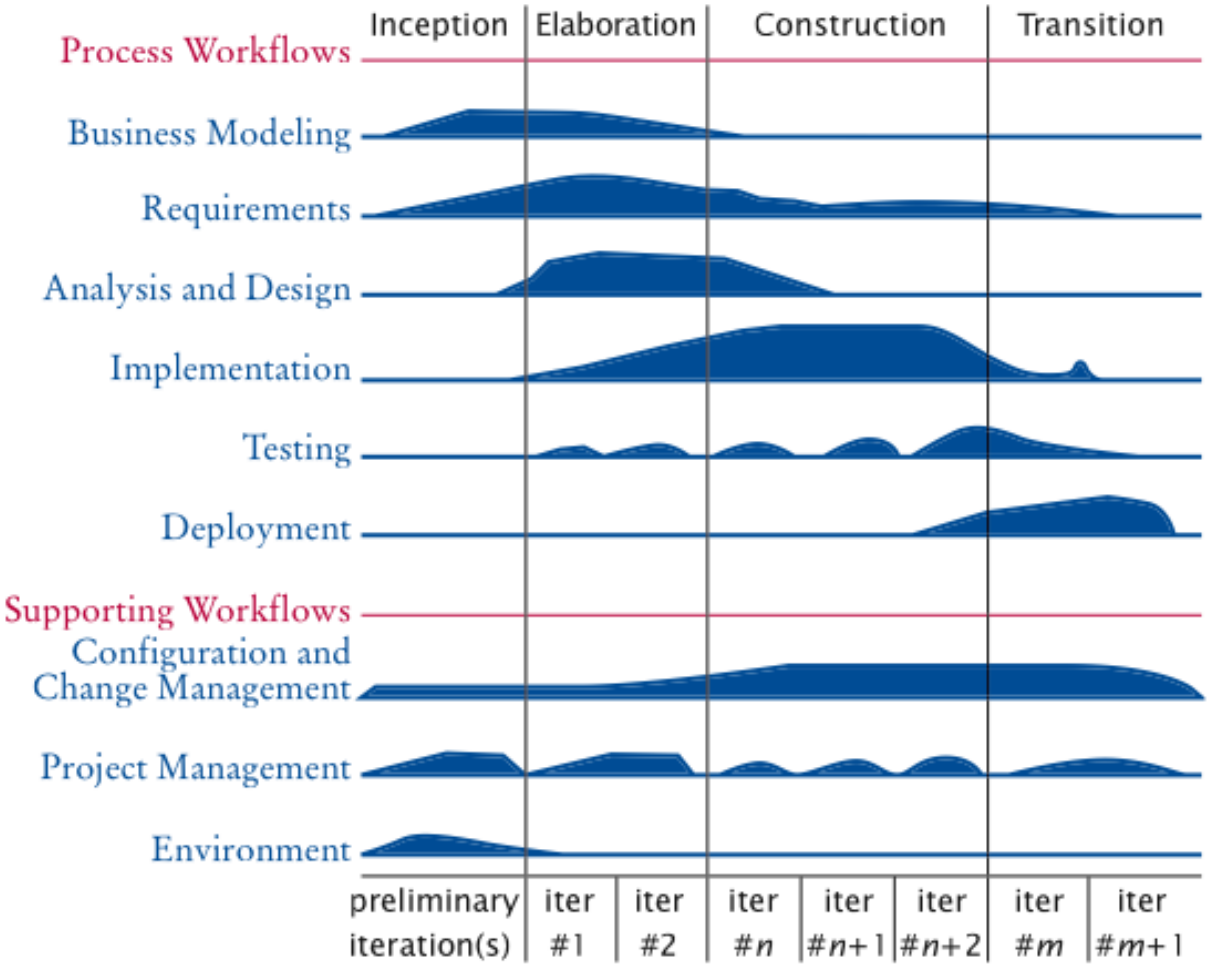


Figure 3 Activity Levels in the Rational Unified Process Methodology

Extreme Programming

- Strives for simplicity
- Removes formal structure
- Focuses on best practices

Extreme Programming

- Realistic planning
  - *Customers make business decisions*
  - *Programmers make technical decisions*
  - *Update plan when it conflicts with reality*
- Small releases
  - *Release a useful system quickly*
  - *Release updates on a very short cycle*
- Metaphor
  - *Programmers have a simple shared story that explains the system*

Extreme Programming

- Simplicity
  - *Design as simply as possible instead of preparing for future complexities*
- Testing
  - *Programmers and customers write test cases*
  - *Test continuously*
- Refactoring
  - *Restructure the system continuously to improve code and eliminate duplication*

Extreme Programming

- Pair programming
  - *Two programmers write code on the same computer*
- Collective ownership
  - *All programmers can change all code as needed*
- Continuous integration
  - *Build the entire system and test it whenever a task is complete*

Extreme Programming

- 40-hour week
  - *Don’t cover up unrealistic schedules with heroic effort*
- On-site customer
  - *A customer is accessible to the programming team at all times*
- Coding standards
  - *Follow standards that emphasize self-documenting code*

Self Check 11.1

Suppose you sign a contract, promising that you will, for an agreed-upon price, design, implement, and test a software package exactly as it has been specified in a requirements document. What is the primary risk you and your customer are facing with this business arrangement?

Answer: It is unlikely that the customer did a perfect job with the requirements document. If you don't accommodate changes, your customer may not like the outcome. If you charge for the changes, your customer may not like the cost.

Self Check 11.2

Does Extreme Programming follow a waterfall or a spiral model?

Answer: An “extreme” spiral model, with lots of iterations.

Self Check 11.3

What is the purpose of the “on-site customer” in Extreme Programming?

Answer: To give frequent feedback as to whether the current iteration of the product fits customer needs.

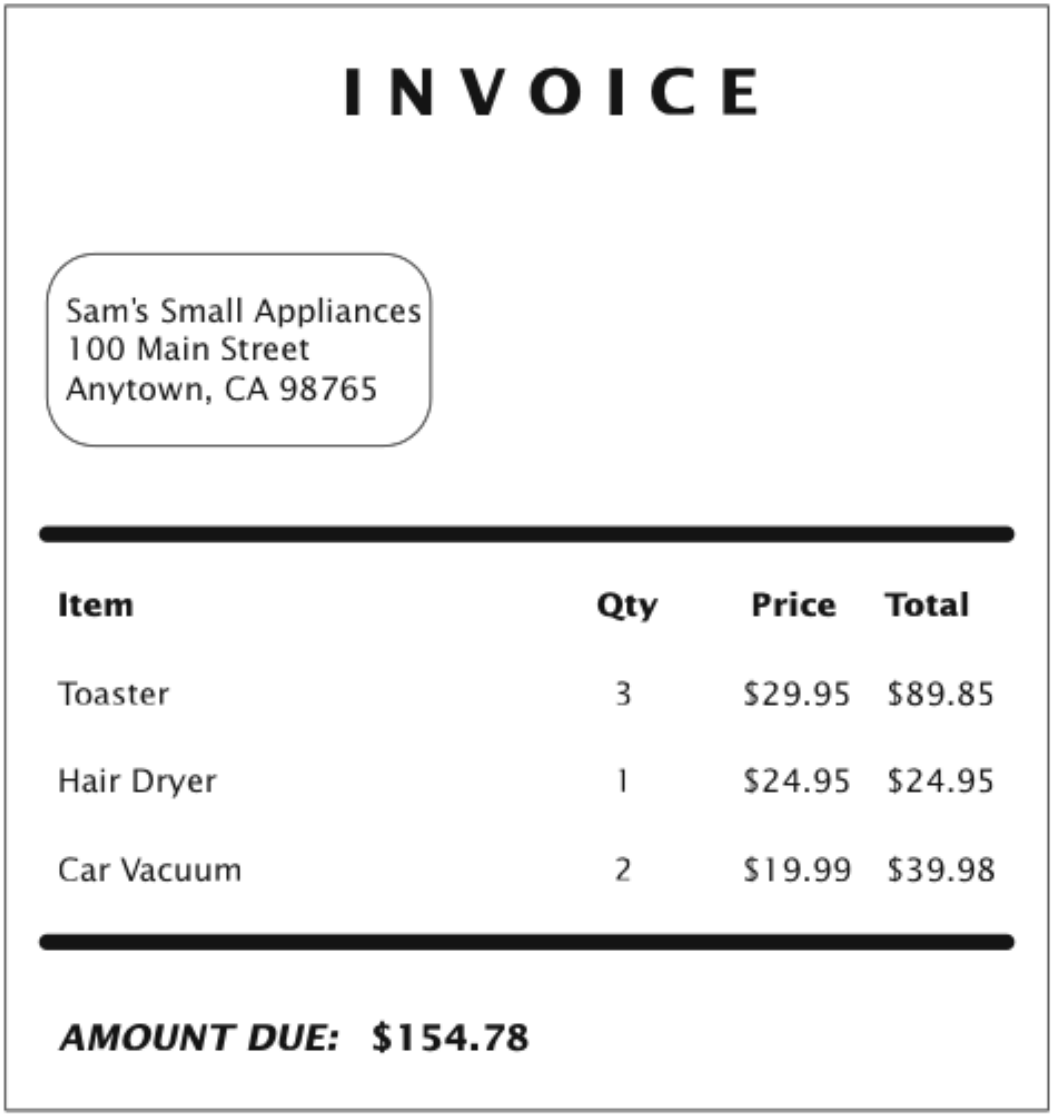
Object-Oriented Design

1. Discover classes
2. Determine responsibilities of each class
3. Describe relationships between the classes

Discovering Classes

- A class represents some useful concept
- Concrete entities: Bank accounts, ellipses, and products
- Abstract concepts: Streams and windows
- Find classes by looking for nouns in the task description
- Define the behavior for each class
- Find methods by looking for verbs in the task description

Example: Invoice



INVOICE

Sam's Small Appliances
100 Main Street
Anytown, CA 98765

Item	Qty	Price	Total
Toaster	3	$29.95	$89.85
Hair Dryer	1	$24.95	$24.95
Car Vacuum	2	$19.99	$39.98

AMOUNT DUE: **$154.78**

Figure 4
An Invoice

Example: Invoice

- Classes that come to mind: `Invoice`, `LineItem`, and `Customer`
- Good idea to keep a list of candidate classes
- Brainstorm, simply put all ideas for classes onto the list
- You can cross not useful ones later

Finding Classes

- Keep the following points in mind:
  - *Class represents set of objects with the same behavior*
    - *Entities with multiple occurrences in problem description are good candidates for objects*
    - *Find out what they have in common*
    - *Design classes to capture commonalities*
  - *Represent some entities as objects, others as primitive types*
    - *Should we make a class* `Address` *or use a* `String`*?*
  - *Not all classes can be discovered in analysis phase*
  - *Some classes may already exist*

CRC Card

- Describes a **c**lass, its **r**esponsibilities, and its **c**ollaborators
- Use an index card for each class
- Pick the class that should be responsible for each method (verb)
- Write the responsibility onto the class card

Continued

CRC Card

- Indicate what other classes are needed to fulfill responsibility (collaborators)

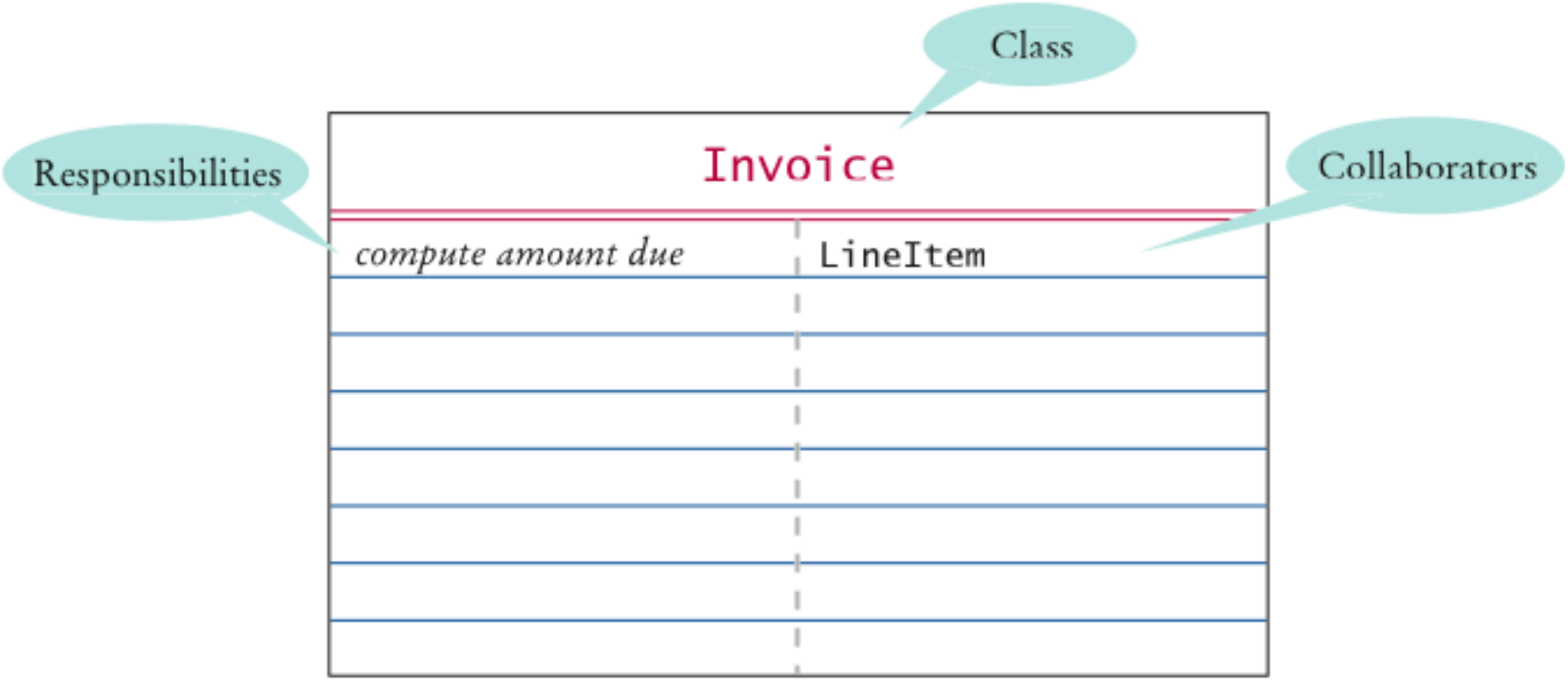


Figure 5 A CRC Card

Self Check 11.4

Suppose the invoice is to be saved to a file. Name a likely collaborator.

Answer: `PrintStream`

Self Check 11.5

Looking at the invoice in Figure 4, what is a likely responsibility of the `Customer` class?

Answer: To produce the shipping address of the customer.

Self Check 11.6

What do you do if a CRC card has ten responsibilities?

Answer: Reword the responsibilities so that they are at a higher level, or come up with more classes to handle the responsibilities.

Relationships Between Classes

- Inheritance
- Aggregation
- Dependency

Inheritance

- *Is-a* relationship
- Relationship between a more general class (superclass) and a more specialized class (subclass)
- Every savings account is a bank account
- Every circle is an ellipse (with equal width and height)
- It is sometimes abused
  - *Should the class* `Tire` *be a subclass of a class* `Circle`*?*
    - *The has-a relationship would be more appropriate*

Aggregation

- *Has-a* relationship
- Objects of one class contain references to objects of another class
- Use an instance variable
  - *A tire has a circle as its boundary:*

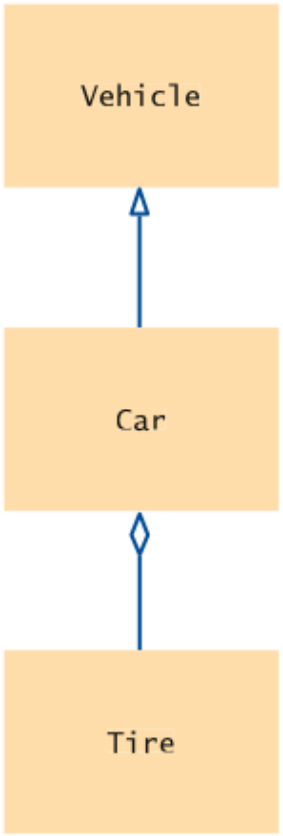
```
class Tire
{
   ...
   private String rating;
   private Circle boundary;
}
```

- Every car has a tire (in fact, it has four)

Example

```
class Car extends Vehicle
{
   ...
   private Tire[] tires;
}
```

Figure 6
UML Notation for
Inheritance and Aggregation



Dependency

- *Uses* relationship
- Example: Many of our applications depend on the `Scanner` class to read input
- Aggregation is a stronger form of dependency
- Use aggregation to remember another object between method calls

UML Relationship Symbols

Relationship	Symbol	Line Style	Arrow Tip
Inheritance		Solid	Triangle
Interface Implementation		Dotted	Triangle
Aggregation		Solid	Diamond
Dependency		Dotted	Open

Self Check 11.7

Consider the `Bank` and `BankAccount` classes of Chapter 7. How are they related?

Answer: Through aggregation. The bank manages bank account objects.

Self Check 11.8

Consider the `BankAccount` and `SavingsAccount` objects of Chapter 10. How are they related?

Answer: Through inheritance.

Self Check 11.9

Consider the `BankAccountTester` class of Chapter 3. Which classes does it depend on?

Answer: The `BankAccount`, `System`, and `PrintStream` classes.

Big Java by Cay Horstmann
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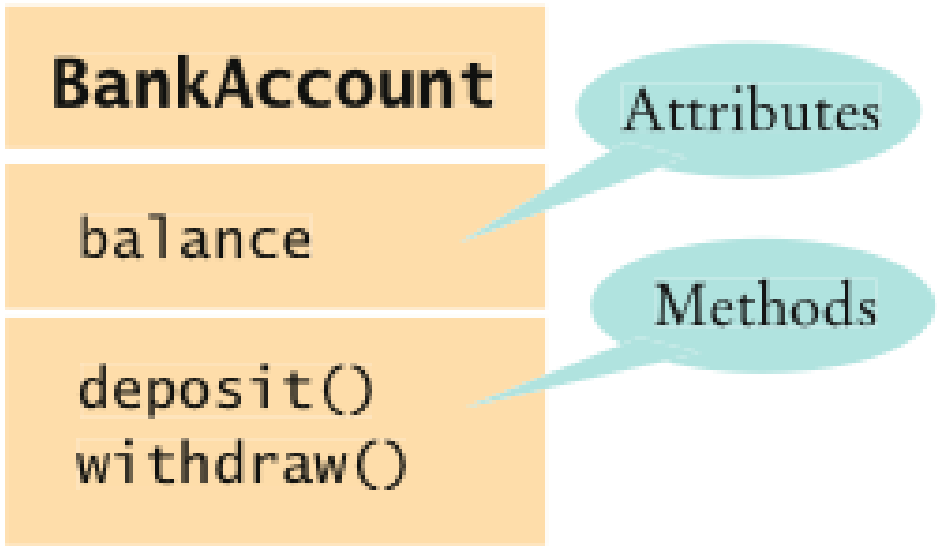
Attributes and Methods in UML Diagrams



Attributes and Methods in a Class Diagram

Multiplicities

- any number (zero or more): *
- one or more: 1..*
- zero or one: 0..1
- exactly one: 1

An Aggregation Relationship with Multiplicities

Aggregation and Association

- Association: More general relationship between classes
- Use early in the design phase
- A class is associated with another if you can navigate from objects of one class to objects of the other
- Given a `Bank` object, you can navigate to `Customer` objects

An Association Relationship

Five-Part Development Process

1. Gather requirements
2. Use CRC cards to find classes, responsibilities, and collaborators
3. Use UML diagrams to record class relationships
4. Use `javadoc` to document method behavior
5. Implement your program

Case Study: Printing an Invoice — Requirements

- Task: Print out an invoice
- Invoice: Describes the charges for a set of products in certain quantities
- Omit complexities
  - *Dates, taxes, and invoice and customer numbers*
- Print invoice
  - *Billing address, all line items, amount due*
- Line item
  - *Description, unit price, quantity ordered, total price*
- For simplicity, do not provide a user interface
- Test program: Adds line items to the invoice and then prints it

Case Study: Sample Invoice

I N V O I C E

Sam's Small Appliances
100 Main Street
Anytown, CA 98765

Description	Price	Qty	Total
Toaster	29.95	3	89.85
Hair dryer	24.95	1	24.95
Car vacuum	19.99	2	39.98

AMOUNT DUE: $154.78

Case Study: Printing an Invoice — CRC Cards

- Discover classes
- Nouns are possible classes:

```
Invoice
Address
LineItem
Product
Description
Price
Quantity
Total
Amount Due
```

Case Study: Printing an Invoice — CRC Cards

- Analyze classes:

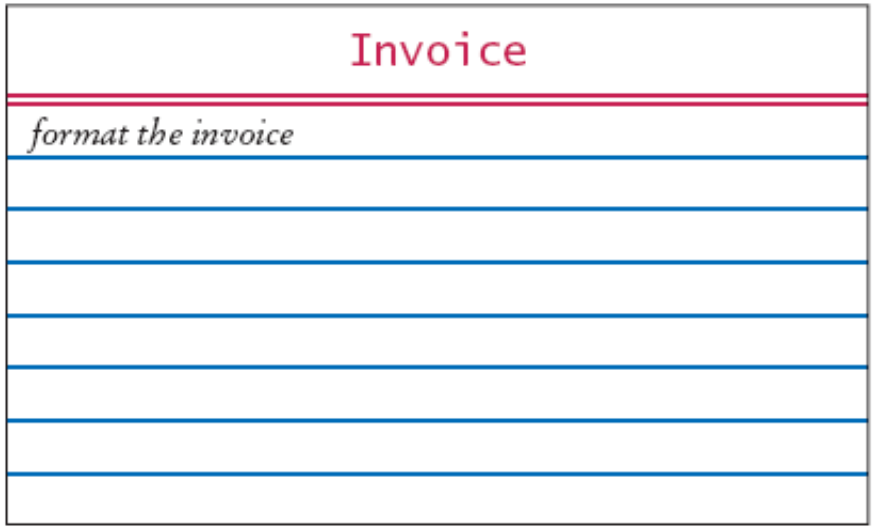
```
Invoice
Address
LineItem     // Records the product and the quantity
Product
Description  // variable of the Product class
Price        // variable of the Product class
Quantity     // Not an attribute of a Product
Total        // Computed - not stored anywhere
Amount Due   // Computed - not stored anywhere
```

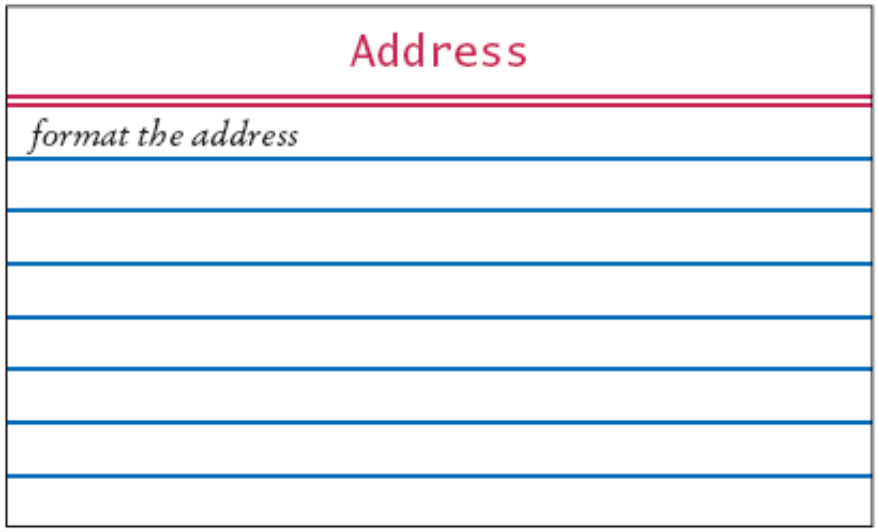
- Classes after a process of elimination:

```
Invoice
Address
LineItem
Product
```

CRC Cards for Printing Invoice

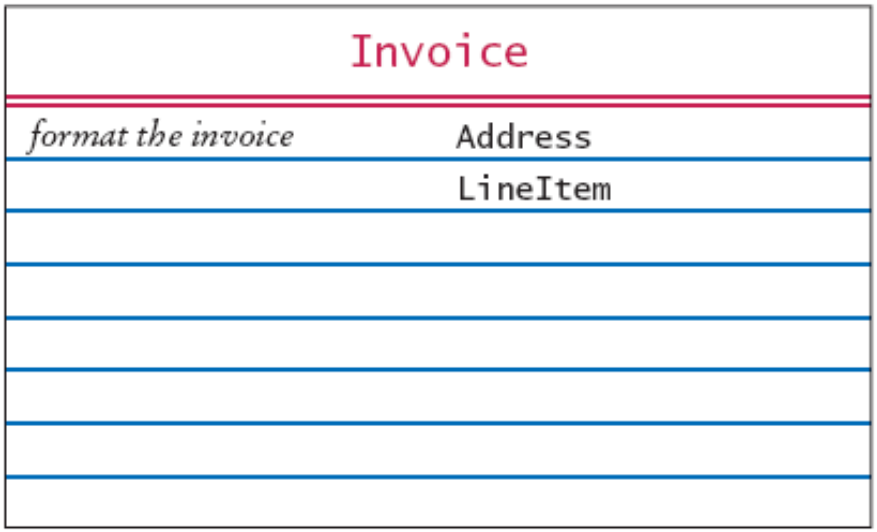
`Invoice` and `Address` must be able to format themselves:





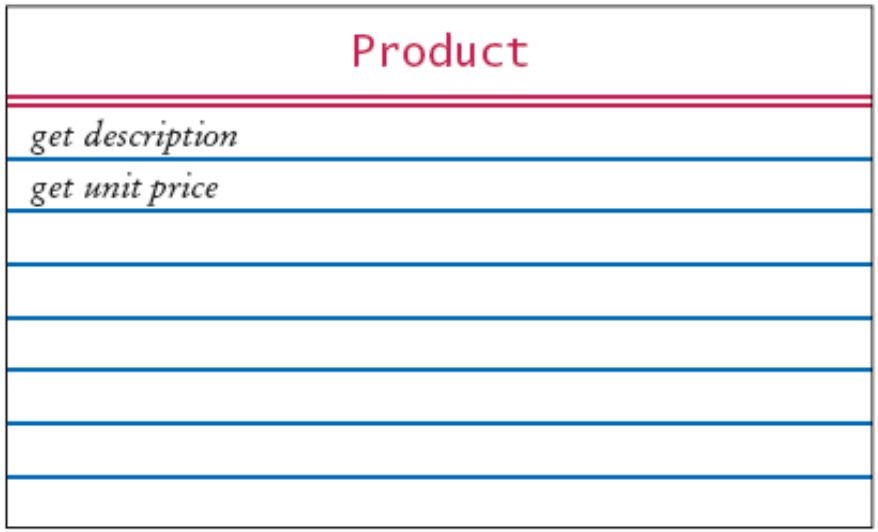
CRC Cards for Printing Invoice

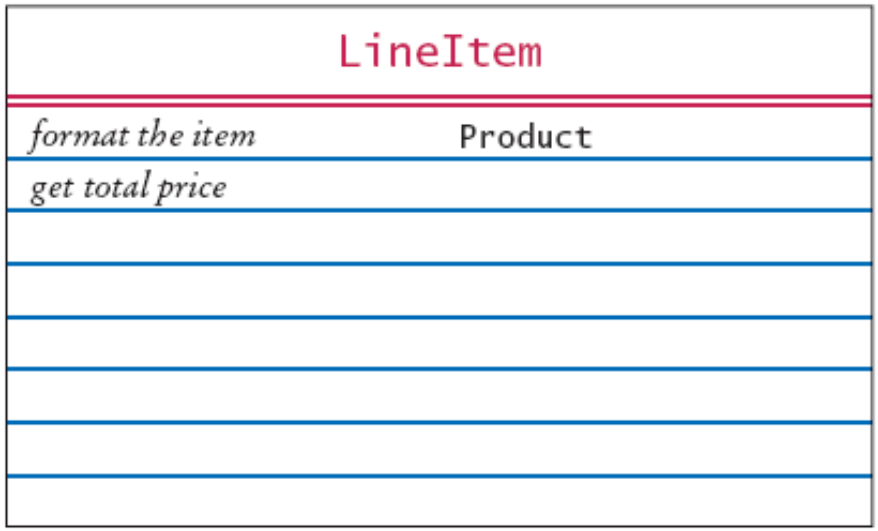
Add collaborators to invoice card:



CRC Cards for Printing Invoice

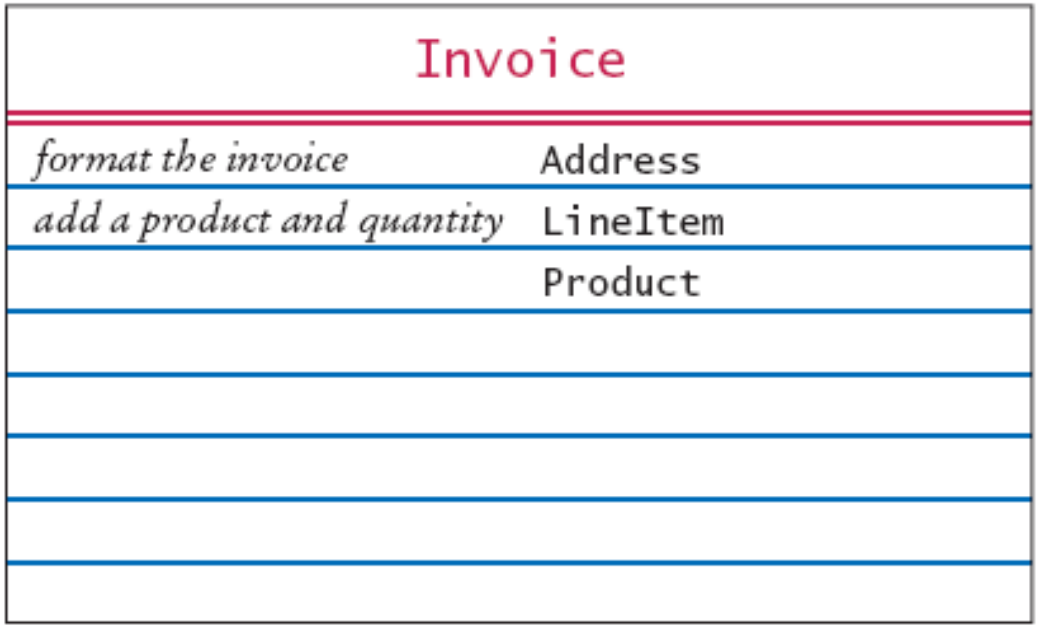
`Product` and `LineItem` CRC cards:





CRC Cards for Printing Invoice

Invoice must be populated with products and quantities:



Printing an Invoice — UML Diagrams

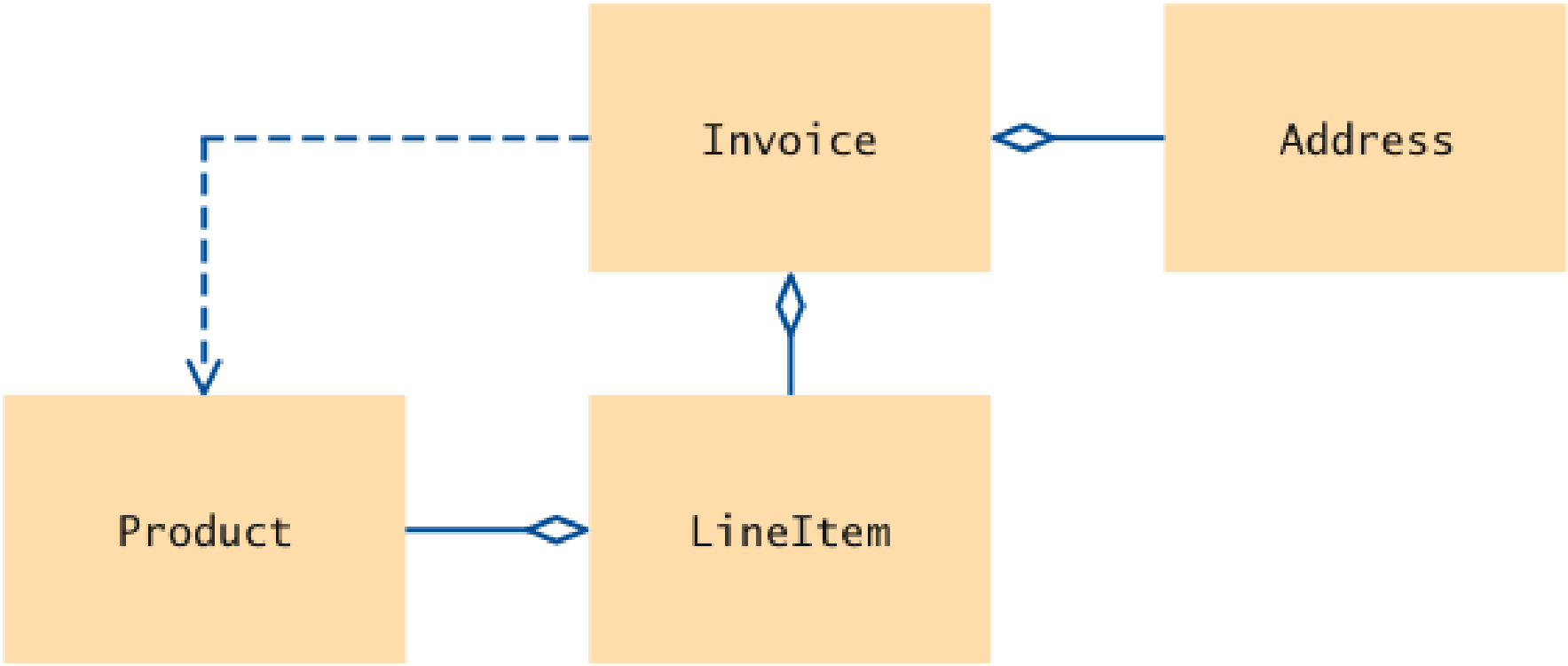


Figure 7 The Relationships Between the Invoice Classes

Printing an Invoice — Method Documentation

- Use `javadoc` documentation to record the behavior of the classes
- Leave the body of the methods blank
- Run `javadoc` to obtain formatted version of documentation in HTML format
- Advantages:
  - *Share HTML documentation with other team members*
  - *Format is immediately useful: Java source files*
  - *Supply the comments of the key methods*

Method Documentation — `Invoice` Class

```
/**
   Describes an invoice for a set of purchased products.
*/
public class Invoice
{
   /**
      Adds a charge for a product to this invoice.
      @param aProduct the product that the customer
         ordered
      @param quantity the quantity of the product
   */
   public void add(Product aProduct, int quantity)
   {
   }
```

Continued

Method Documentation — `Invoice` Class (cont.)

```
   /**
      Formats the invoice.
      @return the formatted invoice
   */
   public String format()
   {
   }
}
```

Method Documentation – `LineItem` Class

```
/**
   Describes a quantity of an article to purchase and its
   price.
*/
public class LineItem
{
   /**
      Computes the total cost of this line item.
      @return the total price
   */
   public double getTotalPrice()
   {
   }
```

Continued

Method Documentation — `LineItem` Class (cont.)

```
   /**
      Formats this item.
      @return a formatted string of this line item
   */
   public String format()
   {
   }
}
```

Method Documentation — `Product` Class

```
/**
   Describes a product with a description and a price.
*/
   public class Product
{
   /**
      Gets the product description.
      @return the description
   */
   public String getDescription()
   {
   }
```

Continued

Method Documentation — `Product` Class (cont.)

```
   /**
      Gets the product price.
      @return the unit price
   */
   public double getPrice()
   {
   }
}
```

Method Documentation — `Address` Class

```
/**
Describes a mailing address.
*/
public class Address
{
   /**
      Formats the address.
      @return the address as a string with three lines
   */
   public String format()
   {
   }
}
```

The Class Documentation in the HTML Format

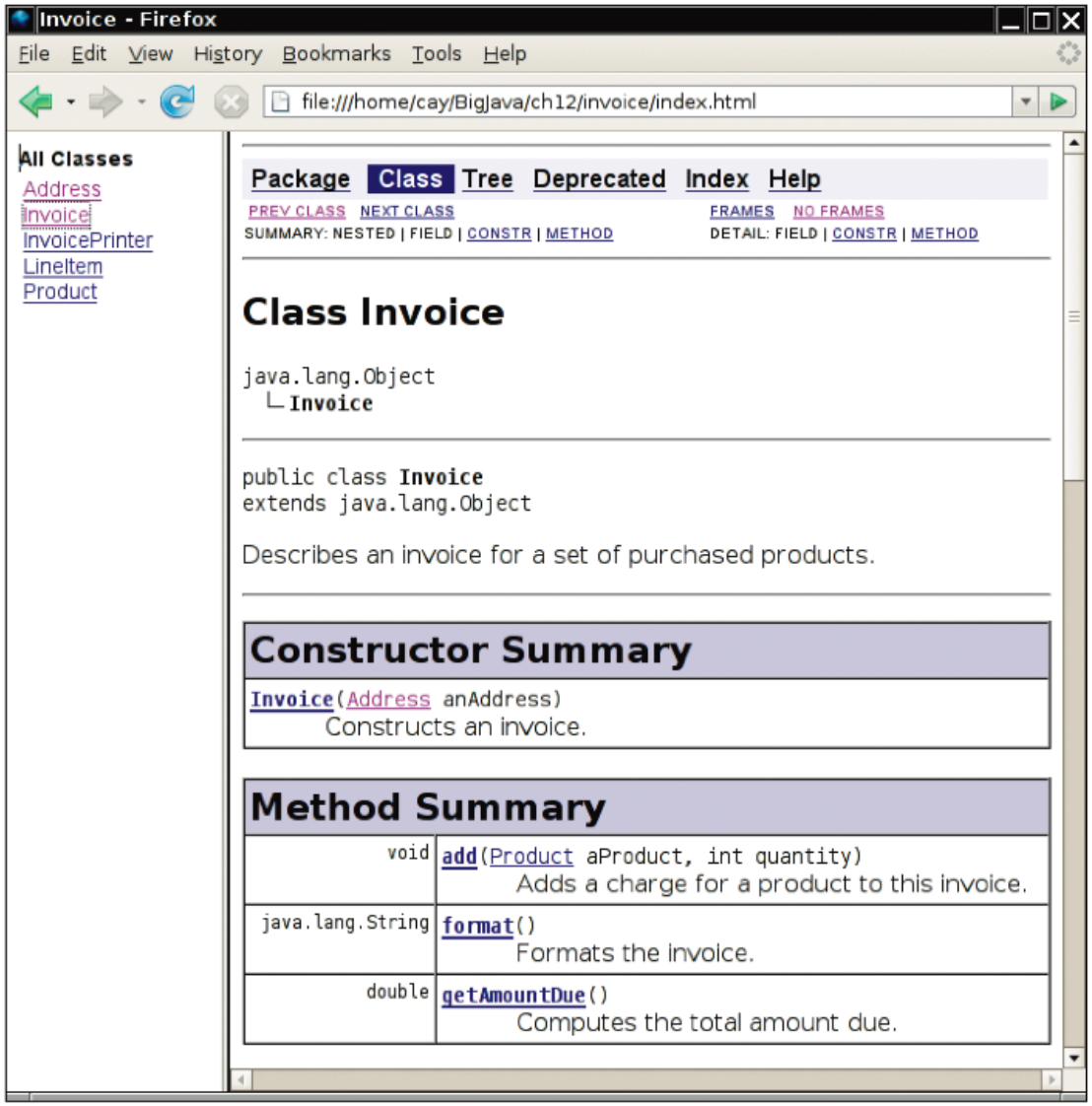


Figure 8 The Class Documentation in HTML Format

Printing an Invoice — Implementation

- The UML diagram will give instance variables
- Look for associated classes
  - *They yield instance variables*

Implementation

- `Invoice` aggregates `Address` and `LineItem`
- Every invoice has one billing address
- An invoice can have many line items:

```
public class Invoice
{
   ...
   private Address billingAddress;
   private ArrayList<LineItem> items;
}
```

Implementation

A line item needs to store a `Product` object and quantity:

```
public class LineItem
{
   ...
   private int quantity;
   private Product theProduct;
}
```

Implementation

- The methods themselves are now very easy
- Example:
  - *`getTotalPrice`* *of* *`LineItem`* *gets the unit price of the product and multiplies it with the quantity:*

```
/**
   Computes the total cost of this line item.
   @return the total price
*/
public double getTotalPrice()
{
   return theProduct.getPrice() * quantity;
}
```

ch11/invoice/InvoicePrinter.java

```
1  /**
2     This program demonstrates the invoice classes by printing
3     a sample invoice.
4  */
5  public class InvoicePrinter
6  {
7     public static void main(String[] args)
8     {
9        Address samsAddress
10             = new Address("Sam&apos;s Small Appliances",
11                "100 Main Street", "Anytown", "CA", "98765");
12
13       Invoice samsInvoice = new Invoice(samsAddress);
14       samsInvoice.add(new Product("Toaster", 29.95), 3);
15       samsInvoice.add(new Product("Hair dryer", 24.95), 1);
16       samsInvoice.add(new Product("Car vacuum", 19.99), 2);
17
18       System.out.println(samsInvoice.format());
19    }
20 }
21
22
23
```

ch11/invoice/Invoice.java

```
1  import java.util.ArrayList;
2
3  /**
4     Describes an invoice for a set of purchased products.
5  */
6  public class Invoice
7  {
8     private Address billingAddress;
9     private ArrayList<LineItem> items;
10
11    /**
12       Constructs an invoice.
13       @param anAddress the billing address
14    */
15    public Invoice(Address anAddress)
16    {
17       items = new ArrayList<LineItem>();
18       billingAddress = anAddress;
19    }
20
```

Continued

ch11/invoice/Invoice.java (cont.)

```
21      /**
22         Adds a charge for a product to this invoice.
23         @param aProduct the product that the customer ordered
24         @param quantity the quantity of the product
25      */
26      public void add(Product aProduct, int quantity)
27      {
28         LineItem anItem = new LineItem(aProduct, quantity);
29         items.add(anItem);
30      }
31
```

Continued

ch11/invoice/Invoice.java (cont.)

```
32      /**
33         Formats the invoice.
34         @return the formatted invoice
35      */
36      public String format()
37      {
38         String r =  "                          I N V O I C E\n\n"
39               + billingAddress.format()
40               + String.format("\n\n%-30s%8s%5s%8s\n",
41                  "Description", "Price", "Qty", "Total");
42
43         for (LineItem item : items)
44         {
45            r = r + item.format() + "\n";
46         }
47
48         r = r + String.format("\nAMOUNT DUE: $%8.2f", getAmountDue());
49
50         return r;
51      }
52
```

Continued

ch11/invoice/Invoice.java (cont.)

```
53      /**
54         Computes the total amount due.
55         @return the amount due
56      */
57      public double getAmountDue()
58      {
59         double amountDue = 0;
60         for (LineItem item : items)
61         {
62            amountDue = amountDue + item.getTotalPrice();
63         }
64         return amountDue;
65      }
66   }
```

ch11/invoice/LineItem.java

```
1  /**
2     Describes a quantity of an article to purchase.
3  */
4  public class LineItem
5  {
6     private int quantity;
7     private Product theProduct;
8
9     /**
10       Constructs an item from the product and quantity.
11       @param aProduct the product
12       @param aQuantity the item quantity
13    */
14    public LineItem(Product aProduct, int aQuantity)
15    {
16       theProduct = aProduct;
17       quantity = aQuantity;
18    }
19
```

Continued

ch11/invoice/LineItem.java (cont.)

```
20      /**
21         Computes the total cost of this line item.
22         @return the total price
23      */
24      public double getTotalPrice()
25      {
26         return theProduct.getPrice() * quantity;
27      }
28
29      /**
30         Formats this item.
31         @return a formatted string of this item
32      */
33      public String format()
34      {
35         return String.format("%-30s%8.2f%5d%8.2f",
36            theProduct.getDescription(), theProduct.getPrice(),
37            quantity, getTotalPrice());
38      }
39   }
```

ch11/invoice/Product.java

```
1  /**
2     Describes a product with a description and a price.
3  */
4  public class Product
5  {
6     private String description;
7     private double price;
8
9     /**
10       Constructs a product from a description and a price.
11       @param aDescription the product description
12       @param aPrice the product price
13    */
14    public Product(String aDescription, double aPrice)
15    {
16       description = aDescription;
17       price = aPrice;
18    }
19
```

Continued

ch11/invoice/Product.java (cont.)

```
20      /**
21         Gets the product description.
22         @return the description
23      */
24      public String getDescription()
25      {
26         return description;
27      }
28
29      /**
30         Gets the product price.
31         @return the unit price
32      */
33      public double getPrice()
34      {
35         return price;
36      }
37   }
38
```

ch11/invoice/Address.java

```
1  /**
2     Describes a mailing address.
3  */
4  public class Address
5  {
6     private String name;
7     private String street;
8     private String city;
9     private String state;
10    private String zip;
11
12    /**
13       Constructs a mailing address.
14       @param aName the recipient name
15       @param aStreet the street
16       @param aCity the city
17       @param aState the two-letter state code
18       @param aZip the ZIP postal code
19    */
```

Continued

ch11/invoice/Address.java (cont.)

```
20      public Address(String aName, String aStreet,
21            String aCity, String aState, String aZip)
22      {
23         name = aName;
24         street = aStreet;
25         city = aCity;
26         state = aState;
27         zip = aZip;
28      }
29
30      /**
31         Formats the address.
32         @return the address as a string with three lines
33      */
34      public String format()
35      {
36         return name + "\n" + street + "\n"
37               + city + ", " + state + " " + zip;
38      }
39   }
40
```

Self Check 11.10

Which class is responsible for computing the amount due? What are its collaborators for this task?

Answer: The `Invoice` class is responsible for computing the amount due. It collaborates with the `LineItem` class.

Self Check 11.11

Why do the format methods return `String` objects instead of directly printing to `System.out`?

Answer: This design decision reduces coupling. It enables us to reuse the classes when we want to show the invoice in a dialog box or on a web page.

Case Study: An Automatic Teller Machine — Requirements

- ATM is used by bank customers. A customer has a
  - *Checking account*
  - *Savings account*
  - *Customer number*
  - *PIN*

Case Study: An Automatic Teller Machine — Requirements

- Customers can select an account
- The balance of the selected account is displayed
- Then, customer can deposit and withdraw money
- Process is repeated until the customer chooses to exit

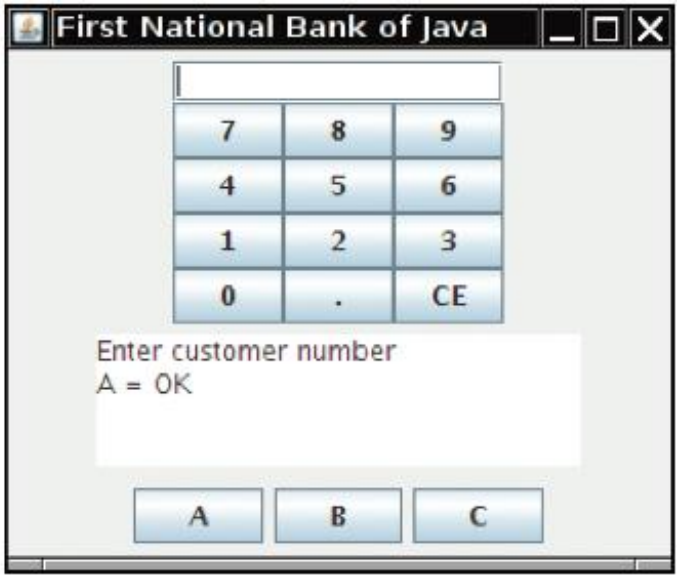
Case Study: An Automatic Teller Machine — Requirements

- Two separate interfaces:
  - *GUI that closely mimics an actual ATM*
  - *Text-based interface*

Case Study: An Automatic Teller Machine — Requirements

- GUI Interface
  - *Keypad*
  - *Display*
  - *Buttons A, B, C*
  - *Button functions depend on the state of the machine*

Figure 9
Graphical User Interface
for the Automatic Teller Machine



Case Study: An Automatic Teller Machine — Requirements

- At start up the customer is expected to
  - *Enter customer number*
  - *Press the A button*
  - *The display shows:*

```
Enter Customer Number
A = OK
```

Case Study: An Automatic Teller Machine — Requirements

- The customer is expected to
  - *Enter a PIN*
  - *Press A button*
  - *The display shows:*

```
Enter PIN
A = OK
```

Case Study: An Automatic Teller Machine — Requirements

- Search for the customer number and PIN
  - *If it matches a bank customer, proceed*
  - *Else return to start up screen*

Case Study: An Automatic Teller Machine — Requirements

- If the customer is authorized
  - *The display shows:*

```
Select Account
A = Checking
B = Savings
C = Exit
```

Case Study: An Automatic Teller Machine — Requirements

- If the user presses C
  - *The ATM reverts to its original state*
  - *ATM asks next user to enter a customer number*
- If the user presses A or B
  - *The ATM remembers selected account*
  - *The display shows:*

```
Balance = balance of selected account
Enter amount and select transaction
A = Withdraw
B = Deposit
C = Cancel
```

Case Study: An Automatic Teller Machine — Requirements

- If the user presses A or B
  - *The value entered is withdrawn or deposited*
  - *Simulation: No money is dispensed and no deposit is accepted*
  - *The ATM reverts to previous state*
- If the user presses C
  - *The ATM reverts to previous state*

Case Study: An Automatic Teller Machine — Requirements

- Text-based interaction
  - *Read input from* `System.in` *instead of the buttons*
  - *Here is a typical dialog:*

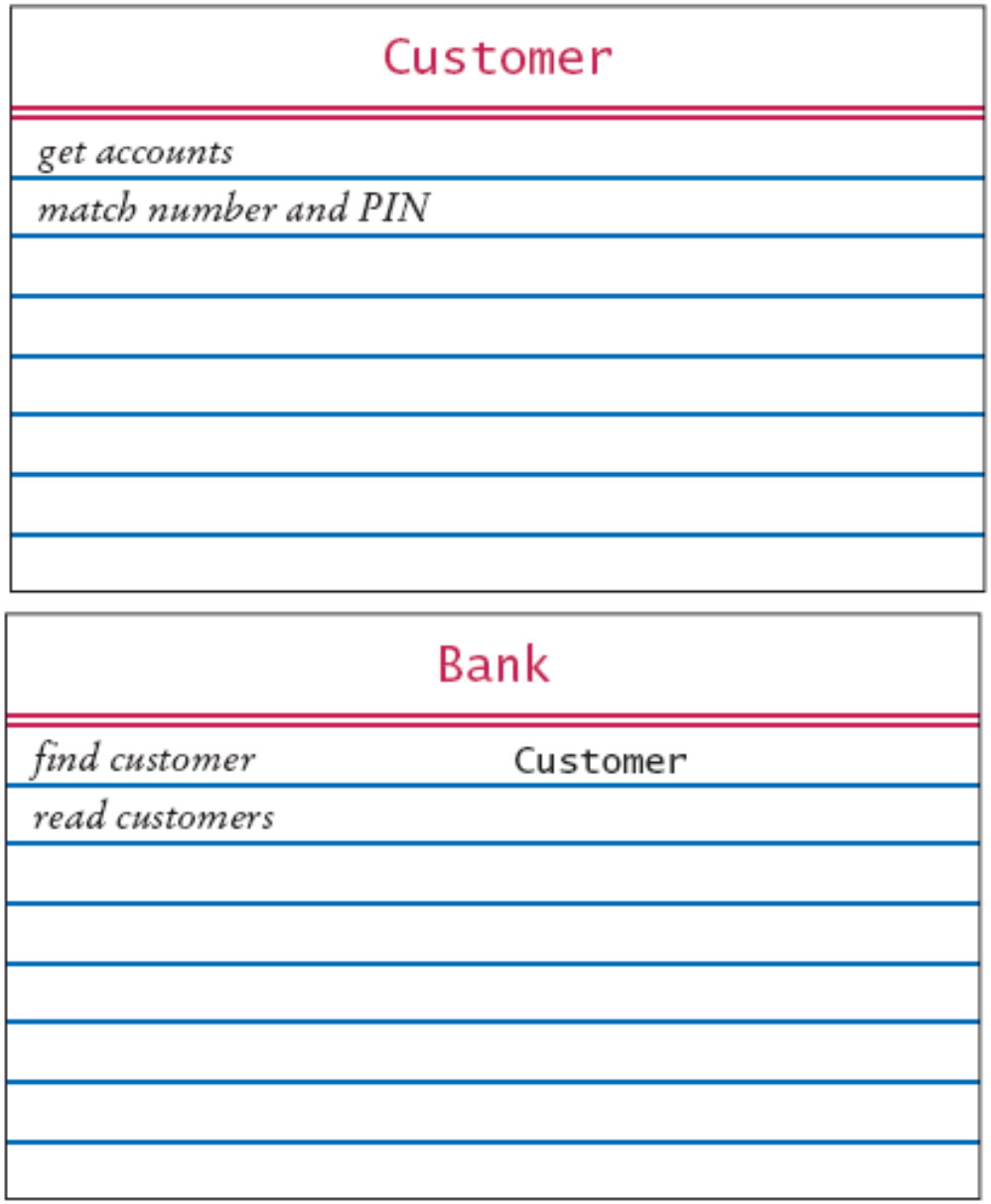
```
Enter account number: 1
Enter PIN: 1234
A=Checking, B=Savings, C=Quit: A
Balance=0.0
A=Deposit, B=Withdrawal, C=Cancel: A
Amount: 1000
A=Checking, B=Savings, C=Quit: C
```

An Automatic Teller Machine – CRC Cards

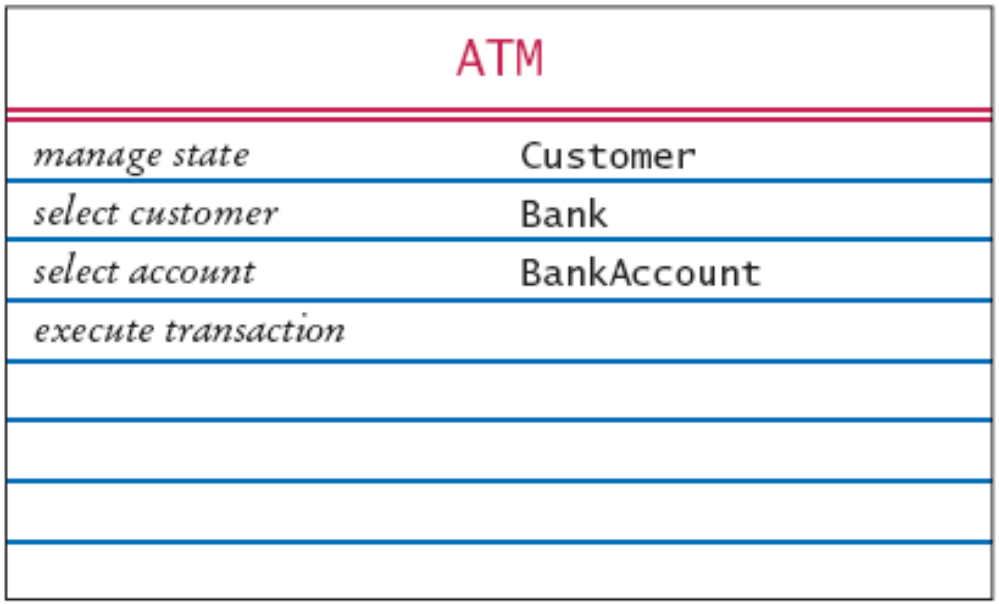
Nouns are possible classes:

```
ATM
User
Keypad
Display
Display message
Button
State
Bank account
Checking account
Savings account
Customer
Customer number
PIN
Bank
```

CRC Cards for Automatic Teller Machine



CRC Cards for Automatic Teller Machine



ATM States

1. START: Enter customer ID
2. PIN: Enter PIN
3. ACCOUNT: Select account
4. TRANSACT: Select transaction

State Diagram for ATM Class

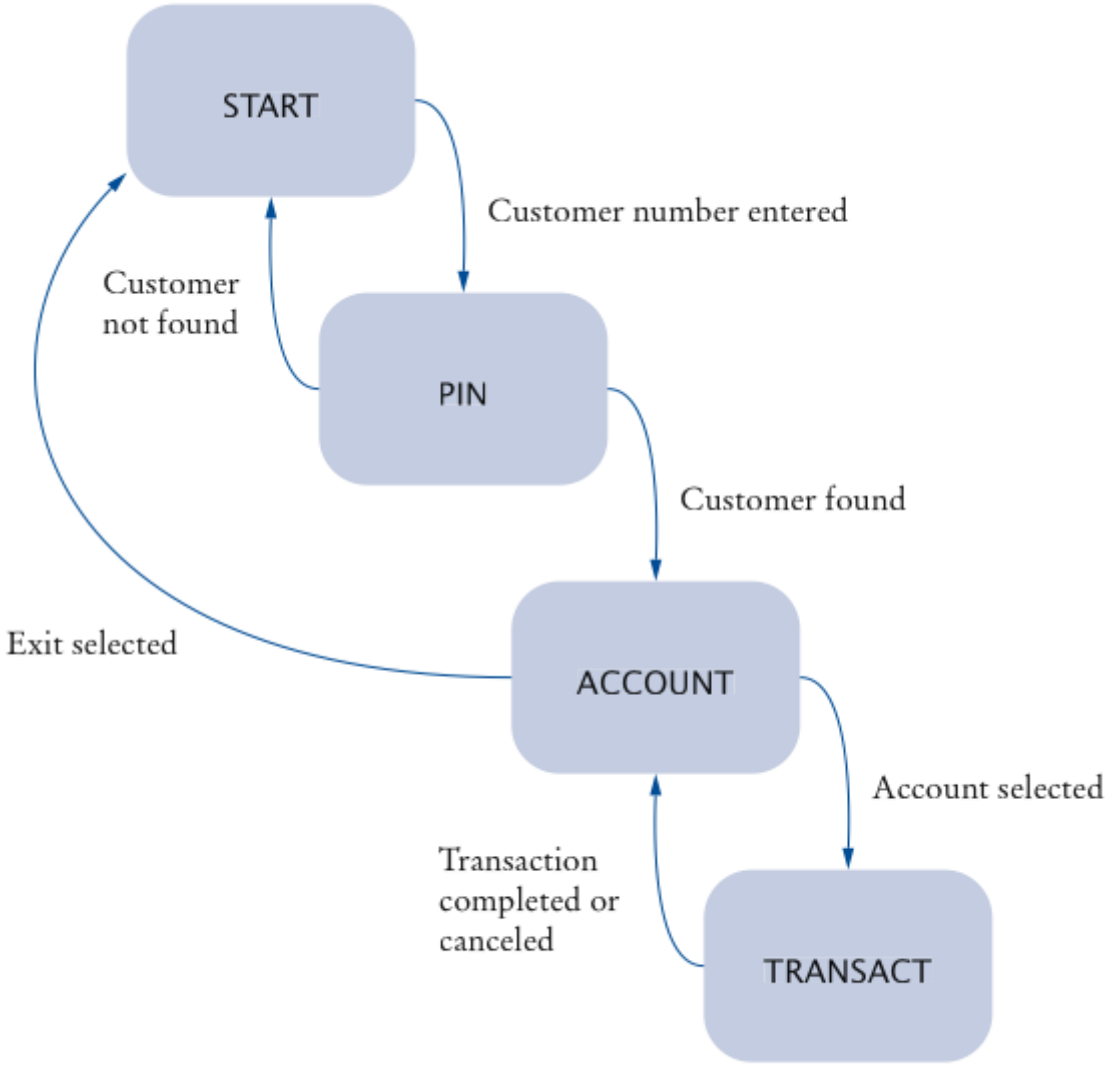


Figure 10 State Diagram for the ATM Class

An Automatic Teller Machine – UML Diagrams

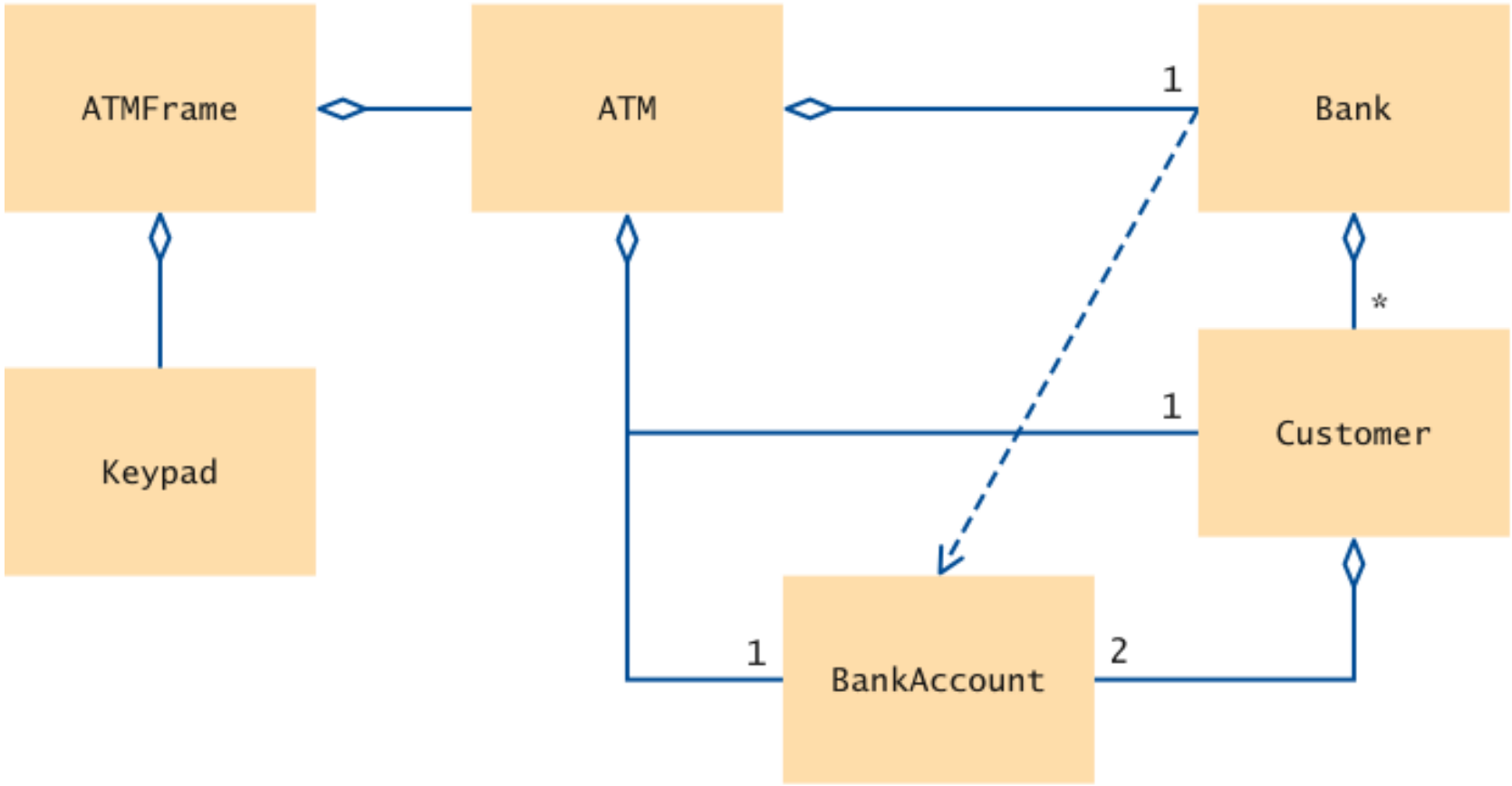


Figure 11 Relationships Between the ATM Classes

Method Documentation ATM Class

```
/**
   An ATM that accesses a bank.
*/
public class ATM
{
   /**
      Constructs an ATM for a given bank.
      @param aBank the bank to which this ATM connects
   */
   public ATM(Bank aBank) { }
   /**
      Sets the current customer number
      and sets state to PIN.
      (Precondition: state is START)
      @param number the customer number
   */
   public void setCustomerNumber(int number) { }
```

Continued

Method Documentation ATM Class (cont.)

```
/**
   Finds customer in bank.
   If found sets state to ACCOUNT, else to START.
   (Precondition: state is PIN)
   @param pin the PIN of the current customer
*/
public void selectCustomer(int pin) { }
/**
   Sets current account to checking or savings. Sets
   state to TRANSACT.
   (Precondition: state is ACCOUNT or TRANSACT)
   @param account one of CHECKING or SAVINGS
*/
```

Continued

Method Documentation ATM Class (cont.)

```
   public void selectAccount(int account) { }
   /**
      Withdraws amount from current account.
      (Precondition: state is TRANSACT)
      @param value the amount to withdraw
   */
   public void withdraw(double value) { }
   ...
}
```

An Automatic Teller Machine — Implementation

- Start implementation with classes that don't depend on others
  - `Keypad`
  - `BankAccount`
- Then implement `Customer` which depends only on `BankAccount`
- This bottom-up approach allows you to test your classes individually

An Automatic Teller Machine — Implementation

- Aggregated classes in UML diagram give instance variables

```
public class ATM
{
   private Bank theBank;
   ...
}
```

- From description of ATM states, it is clear that we require additional instance variables:

```
public class ATM
{
   private int state;
   private Customer currentCustomer;
   private BankAccount currentAccount;
   ...
}
```

An Automatic Teller Machine — Implementation

- Most methods are very straightforward to implement
- Consider `selectCustomer`:

```
/**
   Finds customer in bank.
   If found sets state to ACCOUNT, else to START.
   (Precondition: state is PIN)
   @param pin the PIN of the current customer
*/
```

Continued

An Automatic Teller Machine — Implementation (cont.)

- Description can be almost literally translated to Java instructions:

```
public void selectCustomer(int pin)
{
   assert state == PIN;
   currentCustomer = theBank.findCustomer(customerNumber,
         pin);
   if (currentCustomer == null)
      state = START;
   else
      state = ACCOUNT;
}
```

ch11/atm/ATM.java

```
1  /**
2     An ATM that accesses a bank.
3  */
4  public class ATM
5  {
6     public static final int CHECKING = 1;
7     public static final int SAVINGS = 2;
8
9     private int state;
10    private int customerNumber;
11    private Customer currentCustomer;
12    private BankAccount currentAccount;
13    private Bank theBank;
14
15    public static final int START = 1;
16    public static final int PIN = 2;
17    public static final int ACCOUNT = 3;
18    public static final int TRANSACT = 4;
19
```

Continued

ch11/atm/ATM.java (cont.)

```
20      /**
21         Constructs an ATM for a given bank.
22         @param aBank the bank to which this ATM connects
23      */
24      public ATM(Bank aBank)
25      {
26         theBank = aBank;
27         reset();
28      }
29
30      /**
31         Resets the ATM to the initial state.
32      */
33      public void reset()
34      {
35         customerNumber = -1;
36         currentAccount = null;
37         state = START;
38      }
39
```

Continued

ch11/atm/ATM.java (cont.)

```
40      /**
41         Sets the current customer number
42         and sets state to PIN.
43         (Precondition: state is START)
44         @param number the customer number.
45      */
46      public void setCustomerNumber(int number)
47      {
48         assert state == START;
49         customerNumber = number;
50         state = PIN;
51      }
52
```

Continued

ch11/atm/ATM.java (cont.)

```
53      /**
54         Finds customer in bank.
55         If found sets state to ACCOUNT, else to START.
56         (Precondition: state is PIN)
57         @param pin the PIN of the current customer
58      */
59      public void selectCustomer(int pin)
60      {
61         assert state == PIN;
62         currentCustomer = theBank.findCustomer(customerNumber, pin);
63         if (currentCustomer == null)
64            state = START;
65         else
66            state = ACCOUNT;
67      }
68
```

Continued

ch11/atm/ATM.java (cont.)

```
69      /**
70         Sets current account to checking or savings. Sets
71         state to TRANSACT.
72         (Precondition: state is ACCOUNT or TRANSACT)
73         @param account one of CHECKING or SAVINGS
74      */
75      public void selectAccount(int account)
76      {
77         assert state == ACCOUNT || state == TRANSACT;
78         if (account == CHECKING)
79            currentAccount = currentCustomer.getCheckingAccount();
80         else
81            currentAccount = currentCustomer.getSavingsAccount();
82         state = TRANSACT;
83      }
84
```

Continued

ch11/atm/ATM.java (cont.)

```
85      /**
86         Withdraws amount from current account.
87         (Precondition: state is TRANSACT)
88         @param value the amount to withdraw
89      */
90      public void withdraw(double value)
91      {
92         assert state == TRANSACT;
93         currentAccount.withdraw(value);
94      }
95
96      /**
97         Deposits amount to current account.
98         (Precondition: state is TRANSACT)
99         @param value the amount to deposit
100     */
101     public void deposit(double value)
102     {
103        assert state == TRANSACT;
104        currentAccount.deposit(value);
105     }
106
```

Continued

ch11/atm/ATM.java (cont.)

```
107      /**
108         Gets the balance of the current account.
109         (Precondition: state is TRANSACT)
110         @return the balance
111      */
112      public double getBalance()
113      {
114         assert state == TRANSACT;
115         return currentAccount.getBalance();
116      }
117
118      /**
119         Moves back to the previous state.
120      */
121      public void back()
122      {
123         if (state == TRANSACT)
124            state = ACCOUNT;
125         else if (state == ACCOUNT)
126            state = PIN;
127         else if (state == PIN)
128            state = START;
129      }
130
```

Continued

ch11/atm/ATM.java (cont.)

```
131      /**
132         Gets the current state of this ATM.
133         @return the current state
134      */
135      public int getState()
136      {
137         return state;
138      }
139   }
```

ch11/atm/Bank.java

```
 1  import java.io.File;
 2  import java.io.IOException;
 3  import java.util.ArrayList;
 4  import java.util.Scanner;
 5
 6  /**
 7     A bank contains customers with bank accounts.
 8  */
 9  public class Bank
10  {
11     private ArrayList<Customer> customers;
12
13     /**
14        Constructs a bank with no customers.
15     */
16     public Bank()
17     {
18        customers = new ArrayList<Customer>();
19     }
20
```

Continued

ch11/atm/Bank.java (cont.)

```
21      /**
22         Reads the customer numbers and pins
23         and initializes the bank accounts.
24         @param filename the name of the customer file
25      */
26      public void readCustomers(String filename)
27            throws IOException
28      {
29         Scanner in = new Scanner(new File(filename));
30         while (in.hasNext())
31         {
32            int number = in.nextInt();
33            int pin = in.nextInt();
34            Customer c = new Customer(number, pin);
35            addCustomer(c);
36         }
37         in.close();
38      }
39
```

Continued

ch11/atm/Bank.java (cont.)

```
40      /**
41         Adds a customer to the bank.
42         @param c the customer to add
43      */
44      public void addCustomer(Customer c)
45      {
46         customers.add(c);
47      }
48
49      /**
50         Finds a customer in the bank.
51         @param aNumber a customer number
52         @param aPin a personal identification number
53         @return the matching customer, or null if no customer
54         matches
55      */
56      public Customer findCustomer(int aNumber, int aPin)
57      {
58         for (Customer c : customers)
59         {
60            if (c.match(aNumber, aPin))
61               return c;
62         }
63         return null;
64      }
65   }
```

ch11/atm/Customer.java

```
1  /**
2     A bank customer with a checking and a savings account.
3  */
4  public class Customer
5  {
6     private int customerNumber;
7     private int pin;
8     private BankAccount checkingAccount;
9     private BankAccount savingsAccount;
10
11    /**
12       Constructs a customer with a given number and PIN.
13       @param aNumber the customer number
14       @param aPin the personal identification number
15    */
16    public Customer(int aNumber, int aPin)
17    {
18       customerNumber = aNumber;
19       pin = aPin;
20       checkingAccount = new BankAccount();
21       savingsAccount = new BankAccount();
22    }
23
```

Continued

ch11/atm/Customer.java (cont.)

```
24      /**
25         Tests if this customer matches a customer number
26         and PIN.
27         @param aNumber a customer number
28         @param aPin a personal identification number
29         @return true if the customer number and PIN match
30      */
31      public boolean match(int aNumber, int aPin)
32      {
33         return customerNumber == aNumber && pin == aPin;
34      }
35
36      /**
37         Gets the checking account of this customer.
38         @return the checking account
39      */
40      public BankAccount getCheckingAccount()
41      {
42         return checkingAccount;
43      }
44
```

Continued

ch11/atm/Customer.java (cont.)

```
45      /**
46         Gets the savings account of this customer.
47         @return the checking account
48      */
49      public BankAccount getSavingsAccount()
50      {
51         return savingsAccount;
52      }
53   }
```

ch11/atm/ATMSimulator.java

```
 1  import java.io.IOException;
 2  import java.util.Scanner;
 3
 4  /**
 5     A text-based simulation of an automatic teller machine.
 6  */
 7  public class ATMSimulator
 8  {
 9     public static void main(String[] args)
10     {
11        ATM theATM;
12        try
13        {
14           Bank theBank = new Bank();
15           theBank.readCustomers("customers.txt");
16           theATM = new ATM(theBank);
17        }
18        catch(IOException e)
19        {
20           System.out.println("Error opening accounts file.");
21           return;
22        }
23
```

Continued

ch11/atm/ATMSimulator.java (cont.)

```
24          Scanner in = new Scanner(System.in);
25
26          while (true)
27          {
28             int state = theATM.getState();
29             if (state == ATM.START)
30             {
31                System.out.print("Enter customer number: ");
32                int number = in.nextInt();
33                theATM.setCustomerNumber(number);
34             }
35             else if (state == ATM.PIN)
36             {
37                System.out.print("Enter PIN: ");
38                int pin = in.nextInt();
39                theATM.selectCustomer(pin);
40             }
```

Continued

ch11/atm/ATMSimulator.java (cont.)

```
41            else if (state == ATM.ACCOUNT)
42            {
43               System.out.print("A=Checking, B=Savings, C=Quit: ");
44               String command = in.next();
45               if (command.equalsIgnoreCase("A"))
46                  theATM.selectAccount(ATM.CHECKING);
47               else if (command.equalsIgnoreCase("B"))
48                  theATM.selectAccount(ATM.SAVINGS);
49               else if (command.equalsIgnoreCase("C"))
50                  theATM.reset();
51               else
52                  System.out.println("Illegal input!");
53            }
54            else if (state == ATM.TRANSACT)
55            {
56               System.out.println("Balance=" + theATM.getBalance());
57               System.out.print("A=Deposit, B=Withdrawal, C=Cancel: ");
58               String command = in.next();
```

Continued

ch11/atm/ATMSimulator.java (cont.)

```
59                if (command.equalsIgnoreCase("A"))
60                {
61                   System.out.print("Amount: ");
62                   double amount = in.nextDouble();
63                   theATM.deposit(amount);
64                   theATM.back();
65                }
66                else if (command.equalsIgnoreCase("B"))
67                {
68                   System.out.print("Amount: ");
69                   double amount = in.nextDouble();
70                   theATM.withdraw(amount);
71                   theATM.back();
72                }
73                else if (command.equalsIgnoreCase("C"))
74                   theATM.back();
75                else
76                   System.out.println("Illegal input!");
77             }
78          }
79       }
80    }
```

Continued

ch11/atm/ATMSimulator.java (cont.)

Program Run:

```
Enter account number: 1
Enter PIN: 1234
A=Checking, B=Savings, C=Quit: A
Balance=0.0
A=Deposit, B=Withdrawal, C=Cancel: A
Amount: 1000
A=Checking, B=Savings, C=Quit: C
...
```

ch11/atm/ATMViewer.java

```
1  import java.io.IOException;
2  import javax.swing.JFrame;
3  import javax.swing.JOptionPane;
4
5  /**
6     A graphical simulation of an automatic teller machine.
7  */
8  public class ATMViewer
9  {
10    public static void main(String[] args)
11    {
12       ATM theATM;
13
14       try
15       {
16          Bank theBank = new Bank();
17          theBank.readCustomers("customers.txt");
18          theATM = new ATM(theBank);
19       }
20       catch(IOException e)
21       {
22          JOptionPane.showMessageDialog(null, "Error opening accounts file.");
23          return;
24       }
25
```

Continued

ch11/atm/ATMViewer.java (cont.)

```
26          JFrame frame = new ATMFrame(theATM);
27          frame.setTitle("First National Bank of Java");
28          frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
29          frame.setVisible(true);
30       }
31    }
32
```

ch11/atm/ATMFrame.java

```
1  import java.awt.FlowLayout;
2  import java.awt.GridLayout;
3  import java.awt.event.ActionEvent;
4  import java.awt.event.ActionListener;
5  import javax.swing.JButton;
6  import javax.swing.JFrame;
7  import javax.swing.JPanel;
8  import javax.swing.JTextArea;
9
10 /**
11    A frame displaying the components of an ATM.
12 */
13 public class ATMFrame extends JFrame
14 {
15    private static final int FRAME_WIDTH = 300;
16    private static final int FRAME_HEIGHT = 300;
17
18    private JButton aButton;
19    private JButton bButton;
20    private JButton cButton;
21
22    private KeyPad pad;
23    private JTextArea display;
```

Continued

ch11/atm/ATMFrame.java (cont.)

```
24
25      private ATM theATM;
26
27      /**
28         Constructs the user interface of the ATM frame.
29      */
30      public ATMFrame(ATM anATM)
31      {
32         theATM = anATM;
33
34         // Construct components
35         pad = new KeyPad();
36
37         display = new JTextArea(4, 20);
38
39         aButton = new JButton("  A  ");
40         aButton.addActionListener(new AButtonListener());
41
42         bButton = new JButton("  B  ");
43         bButton.addActionListener(new BButtonListener());
44
```

Continued

ch11/atm/ATMFrame.java (cont.)

```
45          cButton = new JButton("  C  ");
46          cButton.addActionListener(new CButtonListener());
47
48          // Add components
49
50          JPanel buttonPanel = new JPanel();
51          buttonPanel.add(aButton);
52          buttonPanel.add(bButton);
53          buttonPanel.add(cButton);
54
55          setLayout(new FlowLayout());
56          add(pad);
57          add(display);
58          add(buttonPanel);
59          showState();
60
61          setSize(FRAME_WIDTH, FRAME_HEIGHT);
62       }
63
```

Continued

ch11/atm/ATMFrame.java (cont.)

```
64      /**
65         Updates display message.
66      */
67      public void showState()
68      {
69         int state = theATM.getState();
70         pad.clear();
71         if (state == ATM.START)
72            display.setText("Enter customer number\nA = OK");
73         else if (state == ATM.PIN)
74            display.setText("Enter PIN\nA = OK");
75         else if (state == ATM.ACCOUNT)
76            display.setText("Select Account\n"
77                  + "A = Checking\nB = Savings\nC = Exit");
78         else if (state == ATM.TRANSACT)
79            display.setText("Balance = "
80                  + theATM.getBalance()
81                  + "\nEnter amount and select transaction\n"
82                  + "A = Withdraw\nB = Deposit\nC = Cancel");
83      }
84
```

Continued

ch11/atm/ATMFrame.java (cont.)

```
85      class AButtonListener implements ActionListener
86      {
87         public void actionPerformed(ActionEvent event)
88         {
89            int state = theATM.getState();
90            if (state == ATM.START)
91               theATM.setCustomerNumber((int) pad.getValue());
92            else if (state == ATM.PIN)
93               theATM.selectCustomer((int) pad.getValue());
94            else if (state == ATM.ACCOUNT)
95               theATM.selectAccount(ATM.CHECKING);
96            else if (state == ATM.TRANSACT)
97            {
98               theATM.withdraw(pad.getValue());
99               theATM.back();
100           }
101           showState();
102        }
103     }
104
```

Continued

ch11/atm/ATMFrame.java (cont.)

```
105      class BButtonListener implements ActionListener
106      {
107         public void actionPerformed(ActionEvent event)
108         {
109            int state = theATM.getState();
110            if (state == ATM.ACCOUNT)
111               theATM.selectAccount(ATM.SAVINGS);
112            else if (state == ATM.TRANSACT)
113            {
114               theATM.deposit(pad.getValue());
115               theATM.back();
116            }
117            showState();
118         }
119      }
120
```

Continued

ch11/atm/ATMFrame.java (cont.)

```
121      class CButtonListener implements ActionListener
122      {
123         public void actionPerformed(ActionEvent event)
124         {
125            int state = theATM.getState();
126            if (state == ATM.ACCOUNT)
127               theATM.reset();
128            else if (state == ATM.TRANSACT)
129               theATM.back();
130            showState();
131         }
132      }
133   }
```

ch11/atm/KeyPad.java

```
1  import java.awt.BorderLayout;
2  import java.awt.GridLayout;
3  import java.awt.event.ActionEvent;
4  import java.awt.event.ActionListener;
5  import javax.swing.JButton;
6  import javax.swing.JPanel;
7  import javax.swing.JTextField;
8
9  /**
10    A component that lets the user enter a number, using
11    a button pad labeled with digits.
12 */
13 public class KeyPad extends JPanel
14 {
15    private JPanel buttonPanel;
16    private JButton clearButton;
17    private JTextField display;
18
```

Continued

ch11/atm/KeyPad.java (cont.)

```
36          // Add digit buttons
37
38          addButton("7");
39          addButton("8");
40          addButton("9");
41          addButton("4");
42          addButton("5");
43          addButton("6");
44          addButton("1");
45          addButton("2");
46          addButton("3");
47          addButton("0");
48          addButton(".");
49
50          // Add clear entry button
51
52          clearButton = new JButton("CE");
53          buttonPanel.add(clearButton);
54
```

Continued

ch11/atm/KeyPad.java (cont.)

```
55          class ClearButtonListener implements ActionListener
56          {
57             public void actionPerformed(ActionEvent event)
58             {
59                display.setText("");
60             }
61          }
62          ActionListener listener = new ClearButtonListener();
63
64          clearButton.addActionListener(new
65                ClearButtonListener());
66
67          add(buttonPanel, "Center");
68       }
69
```

Continued

ch11/atm/KeyPad.java (cont.)

```
70      /**
71         Adds a button to the button panel
72         @param label the button label
73      */
74      private void addButton(final String label)
75      {
76         class DigitButtonListener implements ActionListener
77         {
78            public void actionPerformed(ActionEvent event)
79            {
80
81               // Don&apos;t add two decimal points
82               if (label.equals(".")
83                     && display.getText().indexOf(".") != -1)
84                  return;
85
86               // Append label text to button
87               display.setText(display.getText() + label);
88            }
89         }
90
```

Continued

ch11/atm/KeyPad.java (cont.)

```
91          JButton button = new JButton(label);
92          buttonPanel.add(button);
93          ActionListener listener = new DigitButtonListener();
94          button.addActionListener(listener);
95       }
96
97       /**
98          Gets the value that the user entered.
99          @return the value in the text field of the keypad
100      */
101      public double getValue()
102      {
103         return Double.parseDouble(display.getText());
104      }
105
106      /**
107         Clears the display.
108      */
109      public void clear()
110      {
111         display.setText("");
112      }
113   }
```

Self Check 11.12

Why does the `Bank` class in this example not store an array list of bank accounts?

Answer: The bank needs to store the list of customers so that customers can log in. We need to locate all bank accounts of a customer, and we chose to simply store them in the customer class. In this program, there is no further need to access bank accounts.

Self Check 11.13

Suppose the requirements change — you need to save the current account balances to a file after every transaction and reload them when the program starts. What is the impact of this change on the design?

Answer: The `Bank` class needs to have an additional responsibility: to load and save the accounts. The bank can carry out this responsibility because it has access to the customer objects and, through them, to the bank accounts.