ICOM 4015: Advanced Programming

Lecture 11

Chapter Eleven: Input/Output and Exception Handling

Chapter Eleven: Input/Ouput and Exception Handling

Chapter Goals

- To be able to read and write text files
- To learn how to throw exceptions
- To be able to design your own exception classes
- To understand the difference between checked and unchecked exceptions
- To learn how to catch exceptions
- To know when and where to catch an exception

Reading Text Files

- Simplest way to read text: use `Scanner` class
- To read from a disk file, construct a `FileReader`
- Then, use the `FileReader` to construct a `Scanner` object

```
FileReader reader = new FileReader("input.txt");
Scanner in = new Scanner(reader);
```

- Use the `Scanner` methods to read data from file

`next`, `nextLine`, `nextInt`, and `nextDouble`

Writing Text Files

- To write to a file, construct a `PrintWriter` object

```
PrintWriter out = new PrintWriter("output.txt");
```

- If file already exists, it is emptied before the new data are written into it
- If file doesn't exist, an empty file is created
- Use `print` and `println` to write into a `PrintWriter`:

```
out.println(29.95);
out.println(new Rectangle(5, 10, 15, 25));
out.println("Hello, World!");
```

- You must close a file when you are done processing it:

```
out.close();
```

  Otherwise, not all of the output may be written to the disk file

FileNotFoundException

- When the input or output file doesn't exist, a `FileNotFoundException` can occur
- To handle the exception, label the main method like this:

```
public static void main(String[] args) throws
      FileNotFoundException
```

A Sample Program

- Reads all lines of a file and sends them to the output file, preceded by line numbers
- Sample input file:

```
Mary had a little lamb
Whose fleece was white as snow.
And everywhere that Mary went,
The lamb was sure to go!
```

- Program produces the output file:

```
/* 1 */ Mary had a little lamb
/* 2 */ Whose fleece was white as snow.
/* 3 */ And everywhere that Mary went,
/* 4 */ The lamb was sure to go!
```

- Program can be used for numbering Java source files

ch11/fileio/LineNumberer.java

```
01: import java.io.FileReader;
02: import java.io.FileNotFoundException;
03: import java.io.PrintWriter;
04: import java.util.Scanner;
05:
06: public class LineNumberer
07: {
08:    public static void main(String[] args)
09:       throws FileNotFoundException
10:    {
11:       Scanner console = new Scanner(System.in);
12:       System.out.print("Input file: ");
13:       String inputFileName = console.next();
14:       System.out.print("Output file: ");
15:       String outputFileName = console.next();
16:
17:       FileReader reader = new FileReader(inputFileName);
18:       Scanner in = new Scanner(reader);
19:       PrintWriter out = new PrintWriter(outputFileName);
20:       int lineNumber = 1;
```

Continued

ch11/fileio/LineNumberer.java (cont.)

```
21:
22:         while (in.hasNextLine())
23:         {
24:            String line = in.nextLine();
25:            out.println("/* " + lineNumber + " */ " + line);
26:            lineNumber++;
27:         }
28:
29:         out.close();
30:     }
31: }
```

Self Check 11.1

What happens when you supply the same name for the input and output files to the `LineNumberer` program?

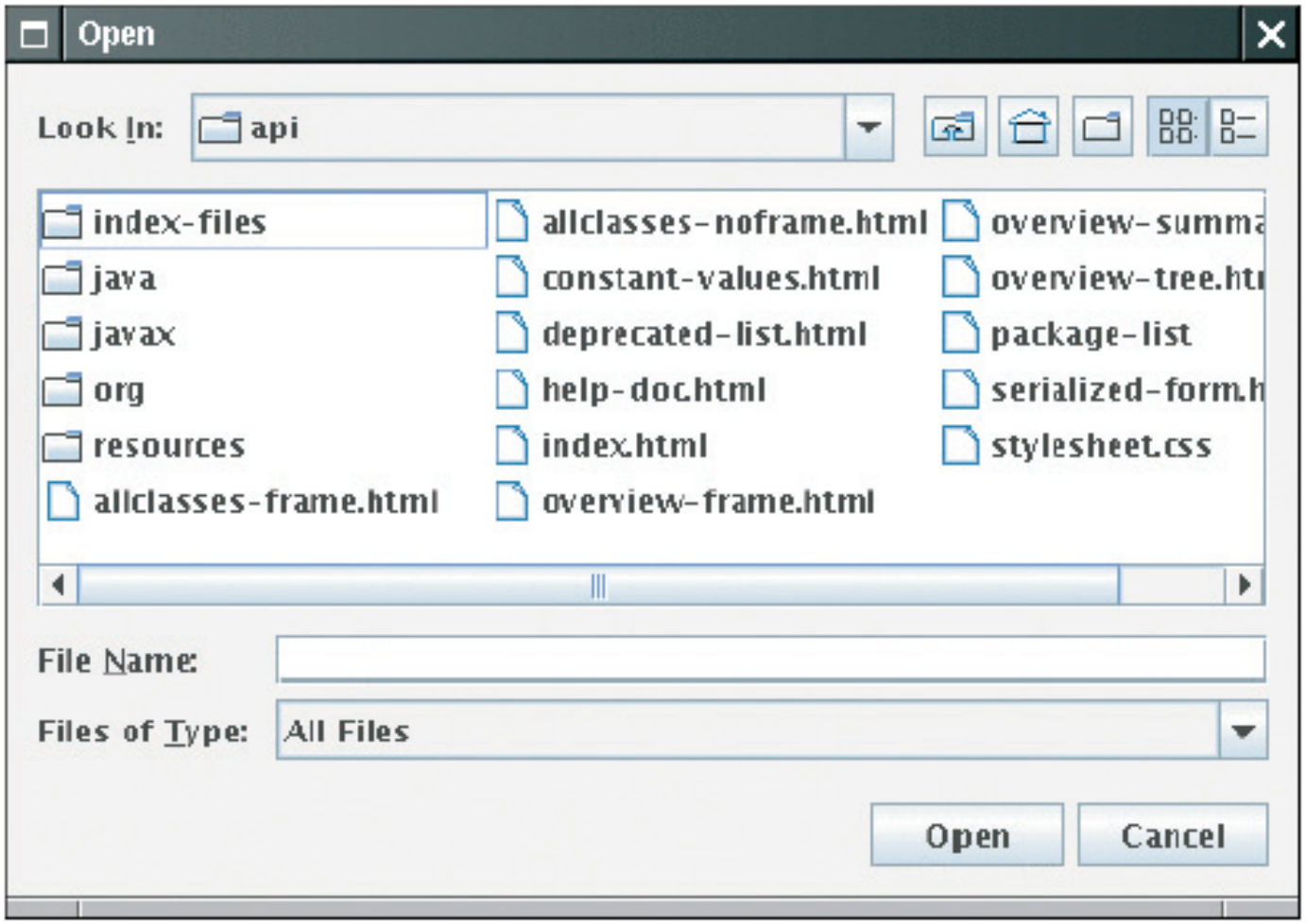
Answer: When the `PrintWriter` object is created, the output file is emptied. Sadly, that is the same file as the input file. The input file is now empty and the `while` loop exits immediately.

Self Check 11.2

What happens when you supply the name of a nonexistent input file to the `LineNumberer` program?

Answer: The program catches a `FileNotFoundException`, prints an error message, and terminates.

File Dialog Boxes



A JFileChooser Dialog Box

Continued

File Dialog Boxes (cont.)

```
JFileChooser chooser = new JFileChooser();
FileReader in = null;
if (chooser.showOpenDialog(null) ==
      JFileChooser.APPROVE_OPTION)
{
   File selectedFile = chooser.getSelectedFile();
   reader = new FileReader(selectedFile);
   . . .
}
```

Throwing Exceptions

- Throw an exception object to signal an exceptional condition
- Example: `IllegalArgumentException`: illegal parameter value

```
IllegalArgumentException exception
      = new IllegalArgumentException("Amount exceeds
      balance");
throw exception;
```

- No need to store exception object in a variable:

```
throw new IllegalArgumentException("Amount exceeds
      balance");
```

- When an exception is thrown, method terminates immediately
  - *Execution continues with an exception handler*

Example

```
public class BankAccount
{
   public void withdraw(double amount)
   {
      if (amount > balance)
      {
         IllegalArgumentException exception
               = new IllegalArgumentException("Amount
               exceeds balance");
         throw exception;
      }
      balance = balance - amount;
   }
   . . .
}
```

Hierarchy of Exception Classes

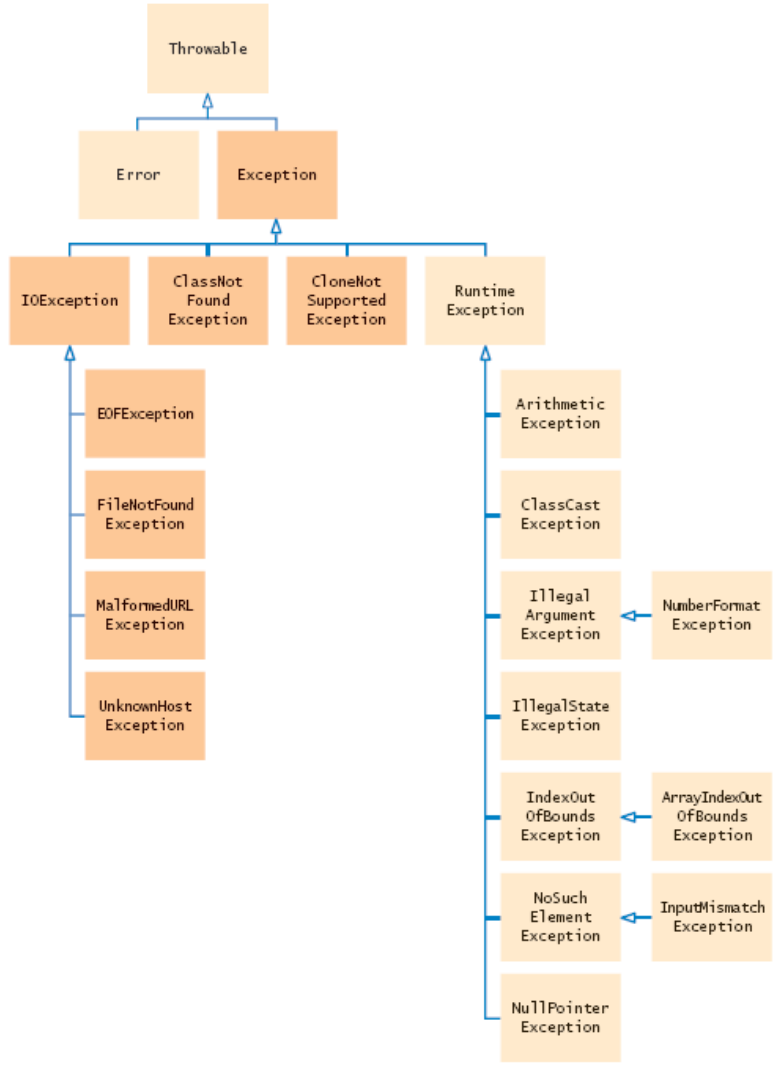


Figure 1 The Hierarchy of Exception Classes

Syntax 11.1 Throwing an Exception

```
throw exceptionObject;
```

Example:

```
throw new IllegalArgumentException();
```

Purpose:

To throw an exception and transfer control to a handler for this exception type.

Self Check 11.3

How should you modify the `deposit` method to ensure that the balance is never negative?

Answer: Throw an exception if the amount being deposited is less than zero.

Self Check 11.4

Suppose you construct a new bank account object with a zero balance and then call `withdraw(10)`. What is the value of `balance` afterwards?

Answer: The balance is still zero because the last statement of the `withdraw` method was never executed.

Checked and Unchecked Exceptions

- Two types of exceptions:
  - *Checked*
    - The compiler checks that you don't ignore them
    - Due to external circumstances that the programmer cannot prevent
    - Majority occur when dealing with input and output
    - For example, `IOException`
  - *Unchecked:*
    - Extend the class `RuntimeException` or `Error`
    - They are the programmer's fault
    - Examples of runtime exceptions:
      `NumberFormatException`
      `IllegalArgumentException`
      `NullPointerException`
    - Example of error:
      `OutOfMemoryError`

Checked and Unchecked Exceptions

- Categories aren't perfect:
  - *`Scanner.nextInt` throws unchecked `InputMismatchException`*
  - *Programmer cannot prevent users from entering incorrect input*
  - *This choice makes the class easy to use for beginning programmers*
- Deal with checked exceptions principally when programming with files and streams
- For example, use a `Scanner` to read a file

```
String filename = . . .;
FileReader reader = new FileReader(filename);
Scanner in = new Scanner(reader);
```

- But, `FileReader` constructor can throw a `FileNotFoundException`

Checked and Unchecked Exceptions

Two choices:

1. *Handle the exception*
2. *Tell compiler that you want method to be terminated when the exception occurs*

- Use `throws` specifier so method can throw a checked exception

```
public void read(String filename) throws
      FileNotFoundException
{
   FileReader reader = new FileReader(filename);
   Scanner in = new Scanner(reader);
   . . .
}
```

- For multiple exceptions:

```
public void read(String filename)
      throws IOException, ClassNotFoundException
```

Continued

Checked and Unchecked Exceptions (cont.)

- Keep in mind inheritance hierarchy:
  If method can throw an `IOException` and `FileNotFoundException`, only use IOException

- Better to declare exception than to handle it incompetently

Syntax 11.2 Exception Specification

```
accessSpecifier returnType methodName(parameterType
      parameterName, . . .)
   throws ExceptionClass, ExceptionClass, . . .
```

Example:

```
public void read(BufferedReader in)
   throws IOException
```

Purpose:

To indicate the checked exceptions that this method can throw.

Self Check 11.5

Suppose a method calls the `FileReader` constructor and the `read` method of the `FileReader` class, which can throw an `IOException`. Which throws specification should you use?

Answer: The specification throws `IOException` is sufficient because `FileNotFoundException` is a subclass of `IOException`.

Self Check 11.6

Why is a `NullPointerException` not a checked exception?

Answer: Because programmers should simply check for null pointers instead of trying to handle a `NullPointerException`.

Catching Exceptions

- Install an exception handler with `try/catch` statement
- `try` block contains statements that may cause an exception
- `catch` clause contains handler for an exception type

Continued

Catching Exceptions (cont.)

- Example:

```
try
{
   String filename = . . .;
   FileReader reader = new FileReader(filename);
   Scanner in = new Scanner(reader); String input =
         in.next();
   int value = Integer.parseInt(input);
   . . .
}
catch (IOException exception)
{
   exception.printStackTrace();
}
catch (NumberFormatException exception)
{
   System.out.println("Input was not a number");
}
```

Catching Exceptions

- Statements in `try` block are executed
- If no exceptions occur, `catch` clauses are skipped
- If exception of matching type occurs, execution jumps to catch clause
- If exception of another type occurs, it is thrown until it is caught by another `try` block
- `catch (IOException exception) block`
  - *`exception` contains reference to the exception object that was thrown*
  - *`catch` clause can analyze object to find out more details*
  - *`exception.printStackTrace()`: printout of chain of method calls that lead to exception*

Syntax 11.3 General Try Block

```
try
{
   statement
   statement
   . . .
}
catch (ExceptionClass exceptionObject)
{
   statement
   statement
   . . .
}
catch (ExceptionClass exceptionObject)
{
   statement
   statement
   . . .
}
. . .
```

Continued

Syntax 11.3 General Try Block (cont.)

Example:

```
try
{
   System.out.println("How old are you?");
   int age = in.nextInt();
   System.out.println("Next year, you'll be " + (age
         + 1));
}
catch (InputMismatchException exception)
{
   exception.printStackTrace();
}
```

Continued

Syntax 11.3 General Try Block (cont.)

Purpose:

To execute one or more statements that may generate exceptions. If an exception occurs and it matches one of the `catch` clauses, execute the first one that matches. If no exception occurs, or an exception is thrown that doesn't match any `catch` clause, then skip the `catch` clauses.

Self Check 11.7

Suppose the file with the given file name exists and has no contents. Trace the flow of execution in the `try` block in this section.

Answer: The `FileReader` constructor succeeds, and `in` is constructed. Then the call `in.next()` throws a `NoSuchElementException`, and the `try` block is aborted. None of the `catch` clauses match, so none are executed. If none of the enclosing method calls catch the exception, the program terminates.

Self Check 11.8

Is there a difference between catching checked and unchecked exceptions?

Answer: No – you catch both exception types in the same way, as you can see from the code example on page 508. Recall that `IOException` is a checked exception and `NumberFormatException` is an unchecked exception.

The `finally` Clause

- Exception terminates current method
- Danger: Can skip over essential code
- Example:

```
reader = new FileReader(filename);
Scanner in = new Scanner(reader);
readData(in);
reader.close(); // May never get here
```

- Must execute `reader.close()` even if exception happens
- Use `finally` clause for code that must be executed "no matter what"

The `finally` Clause

```
FileReader reader = new FileReader(filename);
try
{
   Scanner in = new Scanner(reader);
   readData(in);
}
finally
{
   reader.close(); // if an exception occurs, finally
         clause is also
                  // executed before exception is passed
         to its handler
}
```

The `finally` Clause

- Executed when `try` block is exited in any of three ways:
  - *After last statement of `try` block*
  - *After last statement of catch clause, if this `try` block caught an exception*
  - *When an exception was thrown in `try` block and not caught*
- Recommendation: don't mix `catch` and `finally` clauses in same `try` block

Syntax 11.4 The `finally` Clause

```
try
{
   statement
   statement
   . . .
}
finally
{
   statement
   statement
   . . .
}
```

Continued

Syntax 11.4 The `finally` Clause (cont.)

Example:

```
FileReader reader = new FileReader(filename);
try
{
   readData(reader);
}
finally
{
   reader.close();
}
```

Purpose:

To ensure that the statements in the `finally` clause are executed whether or not the statements in the `try` block throw an exception.

Self Check 11.9

Why was the `out` variable declared outside the `try` block?

Answer: If it had been declared inside the `try` block, its scope would only have extended to the end of the `try` block, and the `catch` clause could not have closed it.

Self Check 11.10

Suppose the file with the given name does not exist. Trace the flow of execution of the code segment in this section.

Answer: The `FileReader` constructor throws an exception. The `finally` clause is executed. Since `reader` is `null`, the call to close is not executed. Next, a `catch` clause that matches the `FileNotFoundException` is located. If none exists, the program terminates.

Designing Your Own Exception Types

- You can design your own exception types – subclasses of `Exception` or `RuntimeException`

- ```
  if (amount > balance)
  {
     throw new InsufficientFundsException(
        "withdrawal of " + amount + " exceeds balance of "
              + balance);
  }
  ```

- Make it an unchecked exception – programmer could have avoided it by calling `getBalance` first
- Extend `RuntimeException` or one of its subclasses
- Supply two constructors
  1. *Default constructor*
  2. *A constructor that accepts a message string describing reason for exception*
  ```

Designing Your Own Exception Types

```
public class InsufficientFundsException
      extends RuntimeException
{
   public InsufficientFundsException() {}

   public InsufficientFundsException(String message)
   {
      super(message);
   }
}
```

Self Check 11.11

What is the purpose of the call `super(message)` in the second `InsufficientFundsException` constructor?

Answer: To pass the exception message string to the `RuntimeException` superclass.

Self Check 11.12

Suppose you read bank account data from a file. Contrary to your expectation, the next input value is not of type `double`. You decide to implement a `BadDataException`. Which exception class should you extend?

Answer: `Exception` or `IOException` are both good choices. Because file corruption is beyond the control of the programmer, this should be a checked exception, so it would be wrong to extend `RuntimeException`.

A Complete Example

- Program
  - *Asks user for name of file*
  - *File expected to contain data values*
  - *First line of file contains total number of values*
  - *Remaining lines contain the data*
  - *Typical input file:*

    3
    1.45
    -2.1
    0.05

A Complete Example

- What can go wrong?
  - *File might not exist*
  - *File might have data in wrong format*
- Who can detect the faults?
  - `FileReader` *constructor will throw an exception when file does not exist*
  - *Methods that process input need to throw exception if they find error in data format*
- What exceptdions can be thrown?
  - `FileNotFoundException` *can be thrown by* `FileReader` *constructor*
  - `IOException` *can be thrown by close method of* `FileReader`
  - `BadDataException`*, a custom checked exception class*

Continued

A Complete Example (cont.)

- Who can remedy the faults that the exceptions report?
  - *Only the main method of* `DataSetTester` *program interacts with user*
  - *Catches exceptions*
  - *Prints appropriate error messages*
  - *Gives user another chance to enter a correct file*

ch11/data/DataAnalyzer.java

```
01: import java.io.FileNotFoundException;
02: import java.io.IOException;
03: import java.util.Scanner;
04:
05: /**
06:    This program reads a file containing numbers and analyzes its contents.
07:    If the file doesn't exist or contains strings that are not numbers, an
08:    error message is displayed.
09: */
10: public class DataAnalyzer
11: {
12:    public static void main(String[] args)
13:    {
14:       Scanner in = new Scanner(System.in);
15:       DataSetReader reader = new DataSetReader();
16:
17:       boolean done = false;
18:       while (!done)
19:       {
20:          try
21:          {
22:             System.out.println("Please enter the file name: ");
23:             String filename = in.next();
```

Continued

ch11/data/DataAnalyzer.java (cont.)

```
24:
25:             double[] data = reader.readFile(filename);
26:             double sum = 0;
27:             for (double d : data) sum = sum + d;
28:             System.out.println("The sum is " + sum);
29:             done = true;
30:          }
31:          catch (FileNotFoundException exception)
32:          {
33:             System.out.println("File not found.");
34:          }
35:          catch (BadDataException exception)
36:          {
37:             System.out.println("Bad data: " + exception.getMessage());
38:          }
39:          catch (IOException exception)
40:          {
41:             exception.printStackTrace();
42:          }
43:       }
44:    }
45: }
```

The `readFile` method of the `DataSetReader` class

- Constructs `Scanner` object
- Calls `readData` method
- Completely unconcerned with any exceptions
- If there is a problem with input file, it simply passes the exception to caller

Continued

The `readFile` method of the `DataSetReader` class (cont.)

```
public double[] readFile(String filename)
      throws IOException, BadDataException
      // FileNotFoundException is an IOException
{
   FileReader reader = new FileReader(filename);
   try
   {
      Scanner in = new Scanner(reader);
      readData(in);
   }
   finally
   {
      reader.close();
   }
   return data;
}
```

The `readData` method of the `DataSetReader` class

- Reads the number of values
- Constructs an array
- Calls `readValue` for each data value

```
private void readData(Scanner in) throws BadDataException
{
   if (!in.hasNextInt())
   throw new BadDataException("Length expected");
   int numberOfValues = in.nextInt();
   data = new double[numberOfValues];

   for (int i = 0; i < numberOfValues; i++)
      readValue(in, i);

   if (in.hasNext())
   throw new BadDataException("End of file expected");
}
```

Continued

The `readData` method of the `DataSetReader` class (cont.)

- Checks for two potential errors
  - *File might not start with an integer*
  - *File might have additional data after reading all values*
- Makes no attempt to catch any exceptions

The `readValue` method of the `DataSetReader` class

```
private void readValue(Scanner in, int i) throws
      BadDataException
{
   if (!in.hasNextDouble())
      throw new BadDataException("Data value expected");
   data[i] = in.nextDouble();
}
```

Animation 11.1 –

```
21      {
22         FileReader reader = new FileReader(filename);
23         try
24         {
25            Scanner in = new Scanner(reader);
26            readData(in);
27         }
28         finally
29         {
30            reader.close();
31         }
32         return data;
33      }
34
35      /**
36         Reads all data.
37         @param in the scanner that scans the data
38      */
```

This animation walks through an exception handling scenario with the `DataAnalyzer` class from Chapter 11. You will learn about throwing exceptions, catching exceptions, and the `finally` clause.

Scenario

1. `DataSetTester.main` calls `DataSetReader.readFile`
2. `readFile` calls `readData`
3. `readData` calls `readValue`
4. `readValue` doesn't find expected value and throws `BadDataException`
5. `readValue` has no handler for exception and terminates
6. `readData` has no handler for exception and terminates
7. `readFile` has no handler for exception and terminates after executing `finally` clause
8. `DataSetTester.main` has handler for `BadDataException`; handler prints a message, and user is given another chance to enter file name

ch11/data/DataSetReader.java

```
01: import java.io.FileReader;
02: import java.io.IOException;
03: import java.util.Scanner;
04:
05: /**
06:    Reads a data set from a file. The file must have the format
07:    numberOfValues
08:    value1
09:    value2
10:    . . .
11: */
12: public class DataSetReader
13: {
14:    /**
15:       Reads a data set.
16:       @param filename the name of the file holding the data
17:       @return the data in the file
18:    */
19:    public double[] readFile(String filename)
20:          throws IOException, BadDataException
21:    {
22:       FileReader reader = new FileReader(filename);
```

Continued

ch11/data/DataSetReader.java (cont.)

```
23:          try
24:          {
25:             Scanner in = new Scanner(reader);
26:             readData(in);
27:          }
28:          finally
29:          {
30:             reader.close();
31:          }
32:          return data;
33:       }
34:
35:       /**
36:          Reads all data.
37:          @param in the scanner that scans the data
38:       */
39:       private void readData(Scanner in) throws BadDataException
40:       {
41:          if (!in.hasNextInt())
42:             throw new BadDataException("Length expected");
43:          int numberOfValues = in.nextInt();
44:          data = new double[numberOfValues];
```

Continued

ch11/data/DataSetReader.java (cont.)

```
45:
46:       for (int i = 0; i < numberOfValues; i++)
47:          readValue(in, i);
48:
49:       if (in.hasNext())
50:          throw new BadDataException("End of file expected");
51:    }
52:
53:    /**
54:       Reads one data value.
55:       @param in the scanner that scans the data
56:       @param i the position of the value to read
57:    */
58:    private void readValue(Scanner in, int i) throws BadDataException
59:    {
60:       if (!in.hasNextDouble())
61:          throw new BadDataException("Data value expected");
62:       data[i] = in.nextDouble();
63:    }
64:
65:    private double[] data;
66: }
```

Self Check 11.13

Why doesn't the `DataSetReader.readFile` method catch any exceptions?

Answer: It would not be able to do much with them. The `DataSetReader` class is a reusable class that may be used for systems with different languages and different user interfaces. Thus, it cannot engage in a dialog with the program user.

Self Check 11.14

Suppose the user specifies a file that exists and is empty. Trace the flow of execution.

Answer: `DataSetTester.main` calls `DataSetReader.readFile`, which calls `readData`. The call `in.hasNextInt()` returns `false`, and `readData` throws a `BadDataException`. The `readFile` method doesn't catch it, so it propagates back to `main`, where it is caught.