

Chapter 11 – Input/Output 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 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/lines/LineNumberer.java

```
1  import java.io.File;
2  import java.io.FileNotFoundException;
3  import java.io.PrintWriter;
4  import java.util.Scanner;
5
6  /**
7   * This program applies line numbers to a file.
8   */
9  public class LineNumberer
10 {
11     public static void main(String[] args) throws FileNotFoundException
12     {
13         // Prompt for the input and output file names
14
15         Scanner console = new Scanner(System.in);
16         System.out.print("Input file: ");
17         String inputFileName = console.next();
18         System.out.print("Output file: ");
19         String outputFileName = console.next();
20     }
```

Continued

Big Java by Cay Horstmann

Copyright © 2009 by John Wiley & Sons. All rights reserved.

ch11/fileio/LineNumberer.java (cont.)

```
21      // Construct the Scanner and PrintWriter objects for reading and writing
22
23      File inputFile = new File(inputFileName);
24      Scanner in = new Scanner(inputFile);
25      PrintWriter out = new PrintWriter(outputFileName);
26      int lineNumber = 1;
27
28      // Read the input and write the output
29
30      while (in.hasNextLine())
31      {
32          String line = in.nextLine();
33          out.println("/ * " + lineNumber + " */ " + line);
34          lineNumber++;
35      }
36
37      in.close();
38      out.close();
39  }
40 }
```

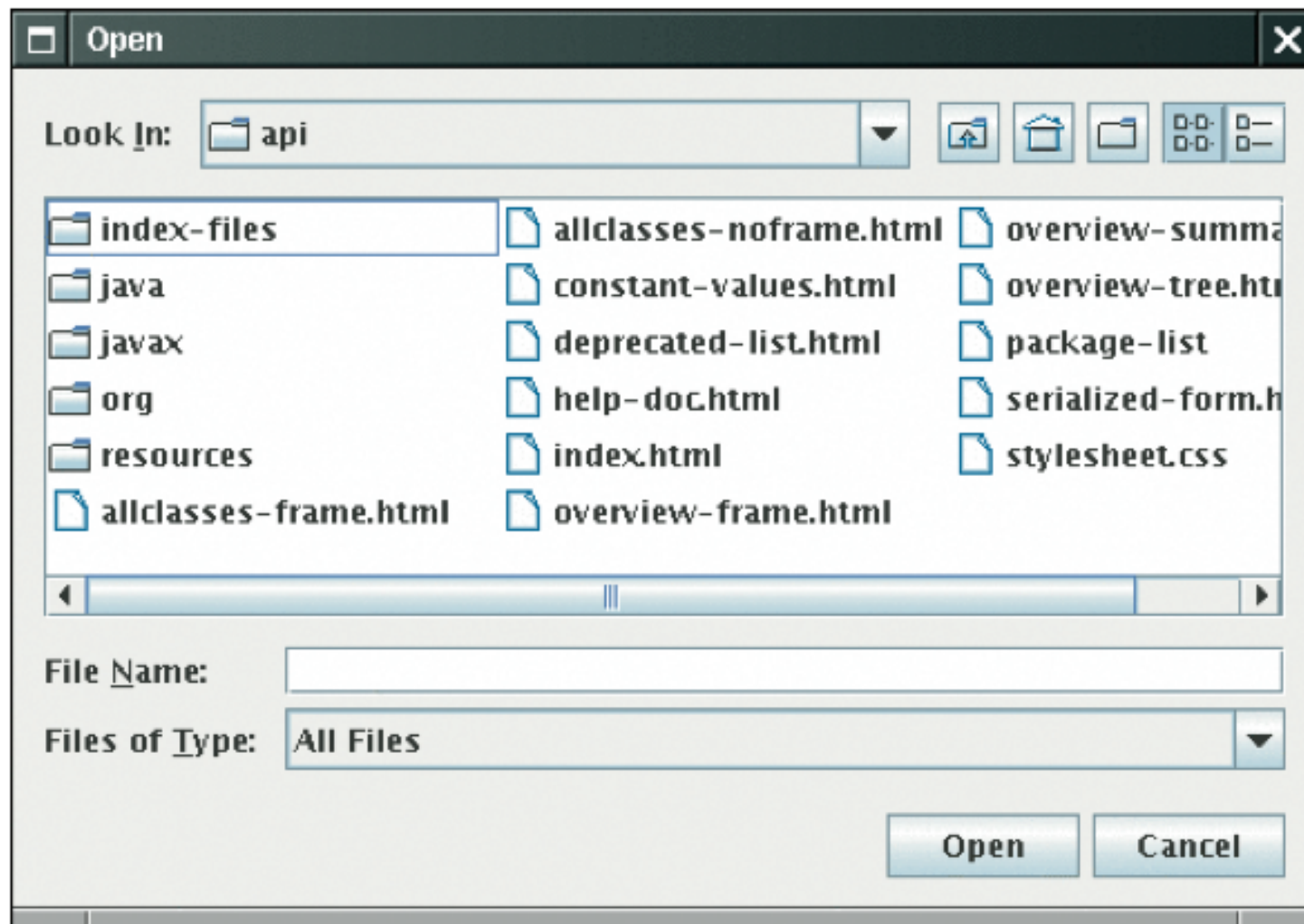

Self Check 11.1

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

Self Check 11.2

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

File Dialog Boxes



A JFileChooser Dialog Box

File Dialog Boxes

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

Reading Text Input: Reading Words

- The `next` method reads a word at a time:

```
while (in.hasNext())  
{  
    String input = in.next();  
    System.out.println(input);  
}
```

- With our sample input, the output is:

```
Mary  
had  
a  
little  
lamb  
...
```

- A *word* is any sequence of characters that is not white space

Reading Text Input: Reading Words

- To specify a pattern for word boundaries, call

```
Scanner.useDelimiter
```

- Example: discard anything that isn't a letter:

```
Scanner in = new Scanner(. . .);  
in.useDelimiter("[^A-Za-z]+");  
...
```

- The notation used for describing the character pattern is called
a regular expression

Reading Text Input: Processing Lines

- The `nextLine` method reads a line of input and consumes the newline character at the end of the line:

```
String line = in.nextLine();
```

- Example: process a file with population data from the [CIA Fact Book](#) with lines like this:

```
China    1330044605
India    1147995898
United States 303824646
...
```

- First read each input line into a string

Reading Text Input: Processing Lines

- Then use the `isDigit` and `isWhitespace` methods to find out where the name ends and the number starts. E.g. locate the first digit:

```
int i = 0;
while (!Character.isDigit(line.charAt(i))) { i++; }
```

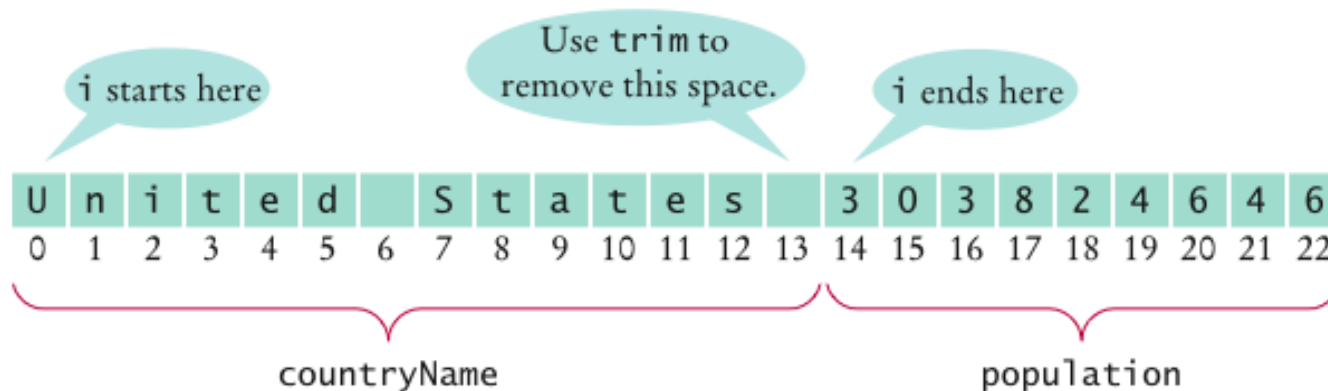
- Then extract the country name and population:

```
String countryName = line.substring(0, i);
String population = line.substring(i);
```


Reading Text Input: Processing Lines

- Use the `trim` method to remove spaces at the end of the country name:

```
countryName = countryName.trim();
```



- To convert the population string to a number, first trim it, then call the `Integer.parseInt` method:

```
int populationValue =  
    Integer.parseInt(population.trim());
```

Reading Text Input: Processing Lines

- Occasionally easier to construct a new `Scanner` object to read the characters from a string:

```
Scanner lineScanner = new Scanner(line);
```

- Then you can use `lineScanner` like any other `Scanner` object, reading words and numbers:

```
String countryName = lineScanner.next();  
while (!lineScanner.hasNextInt())  
{  
    countryName = countryName + " " +  
    lineScanner.next();  
}  
int populationValue = lineScanner.nextInt();
```

Reading Text Input: Reading Numbers

- `nextInt` and `nextDouble` methods consume white space and the next number:

```
double value = in.nextDouble();
```

- If there is no number in the input, then a `InputMismatchException` occurs; e.g.



- To avoid exceptions, use the `hasNextDouble` and `hasNextInt` methods to screen the input:

```
if (in.hasNextDouble())  
{  
    double value = in.nextDouble();  
    . . .  
}
```

Reading Text Input: Reading Numbers

- `nextInt` and `nextDouble` methods do not consume the white space that follows a number
- Example: file contains student IDs and names in this format:

```
1729
Harry Morgan
1730
Diana Lin
. . .
```

- Read the file with these instructions:

```
while (in.hasNextInt())
{
    int studentID = in.nextInt();
    String name = in.nextLine();
    Process the student ID and name
}
```

Reading Text Input: Reading Numbers

- Initially, the input contains

1 7 2 9 \n H a r r y

- After the first call to `nextInt`, the input contains

\n H a r r y

- The call to `nextLine` reads an empty string! The remedy is to add a call to `nextLine` after reading the ID:

```
int studentID = in.nextInt();  
in.nextLine(); // Consume the newline  
String name = in.nextLine();
```

Reading Text Input: Reading Characters

- To read one character at a time, set the delimiter pattern to the empty string:

```
Scanner in = new Scanner(. . .);  
in.useDelimiter("");
```

- Now each call to next returns a string consisting of a single character
- To process the characters:

```
while (in.hasNext())  
{  
    char ch = in.next().charAt(0);  
    Process ch  
}
```

Self Check 11.3

Suppose the input contains the characters `6, 995.0`. What is the value of `number` and `input` after these statements?

```
int number = in.nextInt();  
String input = in.next();
```

Self Check 11.4

Suppose the input contains the characters `6,995.00 12`. What is the value of `price` and `quantity` after these statements?

```
double price = in.nextDouble();  
int quantity = in.nextInt();
```


Self Check 11.5

Your input file contains a sequence of numbers, but sometimes a value is not available and marked as N/A. How can you read the numbers and skip over the markers?

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

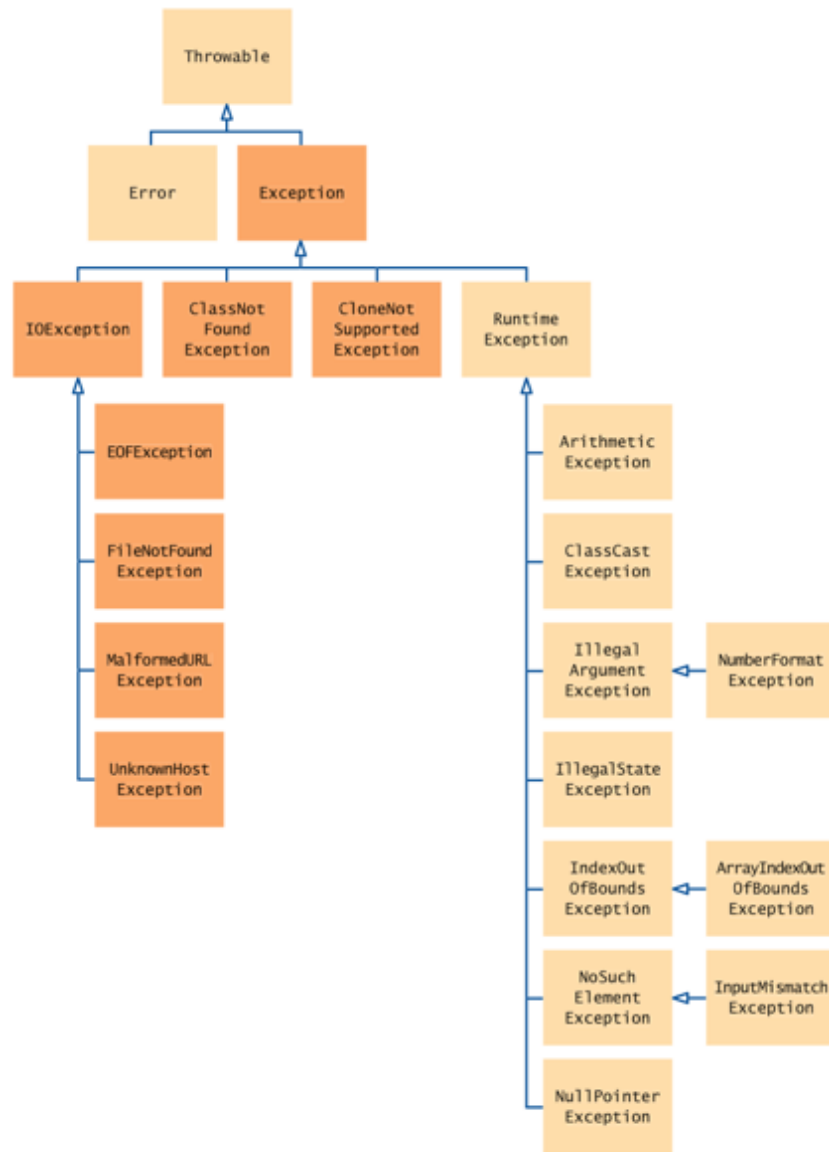


Figure 1 The Hierarchy of Exception Classes

Syntax 11.1 Throwing an Exception

Syntax **throw** *exceptionObject*;

Example

```
if (amount > balance)
{
    throw new IllegalArgumentException("Amount exceeds balance");
}
balance = balance - amount;
```

A new exception object is constructed, then thrown.

Most exception objects can be constructed with an error message.

This line is not executed when the exception is thrown.

Self Check 11.6

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

Self Check 11.7

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

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 throws Clause

Syntax *accessSpecifier returnType methodName(parameterType parameterName, . . .)*
 throws ExceptionClass, ExceptionClass, . . .

Example `public void read(String filename)`
 `throws FileNotFoundException, NoSuchElementException`

You must specify all checked exceptions
that this method may throw.

You may also list unchecked exceptions.

Self Check 11.8

Suppose a method calls the `Scanner` constructor, which can throw a `FileNotFoundException`, and the `nextInt` method of the `Scanner` class, which can cause a `NoSuchElementException` or `InputMismatchException`. Which exceptions should be included in the `throws` clause?

Self Check 11.9

Why is a `NullPointerException` not a checked exception?

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

Big Java by Cay Horstmann

Copyright © 2009 by John Wiley & Sons. All rights reserved.

Catching Exceptions

- 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 Catching Exceptions

Syntax

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

Example

When an IOException is thrown,
execution resumes here.

Additional catch clauses
can appear here.

```
try
{
    Scanner in = new Scanner(new File("input.txt"));
    String input = in.next();
    process(input);
}
catch (IOException exception)
{
    System.out.println("Could not open input file");
}
```

This constructor can throw a
FileNotFoundException.

This is the exception that was thrown.

A FileNotFoundException
is a special case of an IOException.

Self Check 11.10

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.

.

Self Check 11.11

Is there a difference between catching checked and unchecked exceptions?

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:
 1. *After last statement of `try` block*
 2. *After last statement of catch clause, if this `try` block caught an exception*
 3. *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 `finally` Clause

Syntax

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

Example

This variable must be declared outside the try block so that the finally clause can access it.

```
PrintWriter out = new PrintWriter(filename);
try
{
    writeData(out);
}
finally
{
    out.close();
}
```

This code may throw exceptions.

This code is always executed, even if an exception occurs.

Self Check 11.12

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

Self Check 11.13

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

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 11.14

---

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

## Self Check 11.15

---

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?

# Case Study: 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
```

# Case Study: 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 exceptions 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*



# Case Study: A Complete Example

---

- 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

---

```
1 import java.io.FileNotFoundException;
2 import java.io.IOException;
3 import java.util.Scanner;
4
5 /**
6 This program reads a file containing numbers and analyzes its contents.
7 If the file doesn't exist or contains strings that are not numbers, an
8 error message is displayed.
9 */
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 {
```

***Continued***

*Big Java* by Cay Horstmann

Copyright © 2009 by John Wiley & Sons. All rights reserved.

## ch11/data/DataAnalyzer.java (cont.)

---

```
20 try
21 {
22 System.out.println("Please enter the file name: ");
23 String filename = in.next();
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

# The readFile Method of the DataSetReader Class

---

- If there is a problem with input file, it simply passes the exception to caller:

```
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 `readFile` 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");
}
```

# The `readFile` Method of the `DataSetReader` Class

---

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

# The readFile 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: Exception Handling

**DataAnalyzer class**

➔

25

`double[] data = reader.readFile(filename);`

26

`double sum = 0;`

**DataSetReader class**

➔

21

`public double[] readFile(String filename) throws IOException`

22

`{`

23

`File inFile = new File(filename);`

24

`Scanner in = new Scanner(inFile);`

25

26

`try`

27

`{`

28

`readData(in);`

29

`return data;`

30

`}`

31

`finally`

32

`{`

33

`in.close();`

34

`}`

35

`}`

[View code](#)

**Stack trace**

DataAnalyzer.main: 25

DataSetReader.readFile: 21

The readFile method is called.

Exception Handling



## 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

---

```
1 import java.io.File;
2 import java.io.IOException;
3 import java.util.Scanner;
4
5 /**
6 Reads a data set from a file. The file must have the format
7 numberOfValues
8 value1
9 value2
10 ...
11 */
12 public class DataSetReader
13 {
14 private double[] data;
15 }
```

***Continued***

*Big Java* by Cay Horstmann

Copyright © 2009 by John Wiley & Sons. All rights reserved.

## ch11/data/DataSetReader.java (cont.)

---

```
16 /**
17 Reads a data set.
18 @param filename the name of the file holding the data
19 @return the data in the file
20 */
21 public double[] readFile(String filename) throws IOException
22 {
23 File inFile = new File(filename);
24 Scanner in = new Scanner(inFile);
25 try
26 {
27 readData(in);
28 return data;
29 }
30 finally
31 {
32 in.close();
33 }
34 }
35
```

**Continued**

*Big Java* by Cay Horstmann

Copyright © 2009 by John Wiley & Sons. All rights reserved.

## ch11/data/DataSetReader.java (cont.)

---

```
36 /**
37 Reads all data.
38 @param in the scanner that scans the data
39 */
40 private void readData(Scanner in) throws BadDataException
41 {
42 if (!in.hasNextInt())
43 throw new BadDataException("Length expected");
44 int numberOfValues = in.nextInt();
45 data = new double[numberOfValues];
46
47 for (int i = 0; i < numberOfValues; i++)
48 readValue(in, i);
49
50 if (in.hasNext())
51 throw new BadDataException("End of file expected");
52 }
53
```

**Continued**

*Big Java* by Cay Horstmann

Copyright © 2009 by John Wiley & Sons. All rights reserved.

## ch11/data/DataSetReader.java (cont.)

---

```
54 /**
55 Reads one data value.
56 @param in the scanner that scans the data
57 @param i the position of the value to read
58 */
59 private void readValue(Scanner in, int i) throws BadDataException
60 {
61 if (!in.hasNextDouble())
62 throw new BadDataException("Data value expected");
63 data[i] = in.nextDouble();
64 }
65 }
```

## ch11/data/BadDataException.java

---

```
1 import java.io.IOException;
2
3 /**
4 * This class reports bad input data.
5 */
6 public class BadDataException extends IOException
7 {
8 public BadDataException() {}
9 public BadDataException(String message)
10 {
11 super(message);
12 }
13 }
```

## Self Check 11.16

---

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



## Self Check 11.17

---

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