Chapter 11:
Exceptions and Advanced File I/O

Starting Out with Java:
From Control Structures through Objects

Fifth Edition

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Chapter Topics

Chapter 11 discusses the following main topics:

- Handling Exceptions
- Throwing Exceptions
- More about Input/Output Streams
- Advanced Topics:
  - Binary Files,
  - Random Access Files, and
  - Object Serialization

Handling Exceptions

- An exception is an object that is generated as the result of an error or an unexpected event.
- Exception are said to have been “thrown.”
- It is the programmers responsibility to write code that detects and handles exceptions.
- Unhandled exceptions will crash a program.
- Example: BadArray.java
- Java allows you to create exception handlers.

Handling Exceptions

- An *exception handler* is a section of code that gracefully responds to exceptions.
- The process of intercepting and responding to exceptions is called *exception handling*.
- The *default exception handler* deals with unhandled exceptions.
- The default exception handler prints an error message and crashes the program.

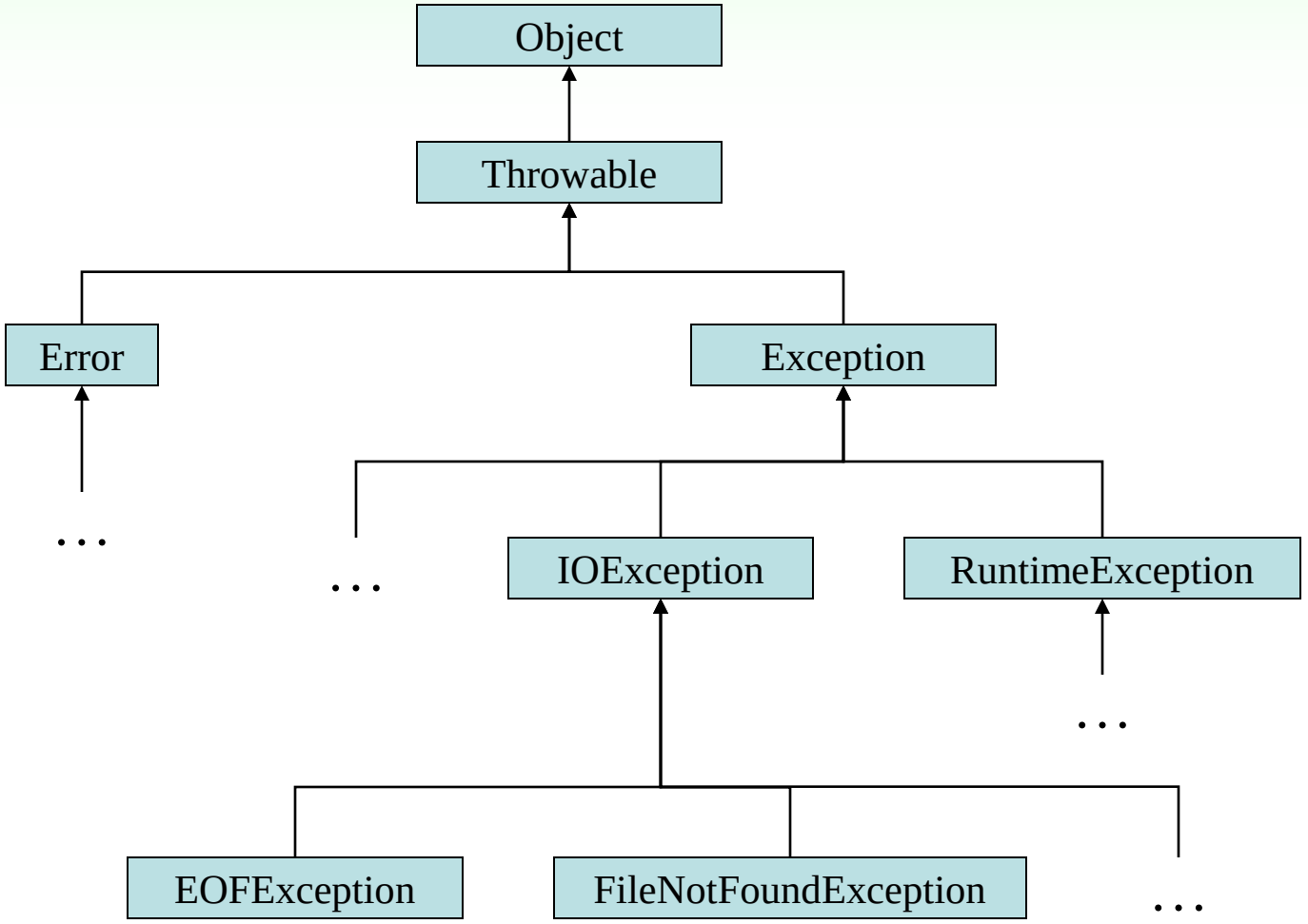
Exception Classes

- An exception is an object.
- Exception objects are created from classes in the Java API hierarchy of exception classes.
- All of the exception classes in the hierarchy are derived from the `Throwable` class.
- `Error` and `Exception` are derived from the `Throwable` class.

Exception Classes

- Classes that are derived from `Error`:
  - are for exceptions that are thrown when critical errors occur. (i.e.)
    - an internal error in the Java Virtual Machine, or
    - running out of memory.
- Applications should not try to handle these errors because they are the result of a serious condition.
- Programmers should handle the exceptions that are instances of classes that are derived from the `Exception` class.

Exception Classes



Handling Exceptions

- To handle an exception, you use a *try* statement.

```
try
{
   (try block statements...)
}
catch (ExceptionType ParameterName)
{
   (catch block statements...)
}
```

- First the keyword `try` indicates a block of code will be attempted (the curly braces are required).
- This block of code is known as a *try block*.

Handling Exceptions

- A *try block* is:
  - one or more statements that are executed, and
  - can potentially throw an exception.
- The application will not halt if the try block throws an exception.
- After the try block, a `catch` clause appears.

Handling Exceptions

- A catch clause begins with the key word `catch`:

```
catch (ExceptionType ParameterName)
```

  - *`ExceptionType`* is the name of an exception class and
  - *`ParameterName`* is a variable name which will reference the exception object if the code in the try block throws an exception.
- The code that immediately follows the catch clause is known as a *catch block* (the curly braces are required).
- The code in the catch block is executed if the try block throws an exception.

Handling Exceptions

- This code is designed to handle a `FileNotFoundException` if it is thrown.

```
try
{
  File file = new File ("MyFile.txt");
  Scanner inputFile = new Scanner(file);
}
catch (FileNotFoundException e)
{
  System.out.println("File not found.");
}
```

- The Java Virtual Machine searches for a `catch` clause that can deal with the exception.
- Example: OpenFile.java

Handling Exceptions

- The parameter must be of a type that is compatible with the thrown exception's type.
- After an exception, the program will continue execution at the point just past the catch block.

Handling Exceptions

- Each exception object has a method named `getMessage` that can be used to retrieve the default error message for the exception.
- Example:
  - ExceptionMessage.java
  - ParseIntError.java

Polymorphic References To Exceptions

- When handling exceptions, you can use a polymorphic reference as a parameter in the `catch` clause.
- Most exceptions are derived from the `Exception` class.
- A `catch` clause that uses a parameter variable of the `Exception` type is capable of catching any exception that is derived from the `Exception` class.

Polymorphic References To Exceptions

```
try
{
   number = Integer.parseInt(str);
}
catch (Exception e)
{
   System.out.println("The following error occurred: "
                      + e.getMessage());
}
```

- The `Integer` class's `parseInt` method throws a `NumberFormatException` object.
- The `NumberFormatException` class is derived from the `Exception` class.

Handling Multiple Exceptions

- The code in the try block may be capable of throwing more than one type of exception.
- A `catch` clause needs to be written for each type of exception that could potentially be thrown.
- The JVM will run the first compatible `catch` clause found.
- The `catch` clauses must be listed from most specific to most general.
- Example: SalesReport.java, SalesReport2.java

Exception Handlers

- There can be many polymorphic catch clauses.
- A try statement may have only one `catch` clause for each specific type of exception.

```
try
{
  number = Integer.parseInt(str);
}
catch (NumberFormatException e)
{
  System.out.println("Bad number format.");
}
catch (NumberFormatException e) // ERROR!!!
{
  System.out.println(str + " is not a number.");
}
```

Exception Handlers

- The `NumberFormatException` class is derived from the `IllegalArgumentException` class.

```
try
{
  number = Integer.parseInt(str);
}
catch (IllegalArgumentException e)
{
  System.out.println("Bad number format.");
}
catch (NumberFormatException e) // ERROR!!!
{
  System.out.println(str + " is not a number.");
}
```

Exception Handlers

- The previous code could be rewritten to work, as follows, with no errors:

```
try
{
  number = Integer.parseInt(str);
}
catch (NumberFormatException e)
{
  System.out.println(str +
                " is not a number.");
}
catch (IllegalArgumentException e) //OK
{
  System.out.println("Bad number format.");
}
```

The `finally` Clause

- The try statement may have an optional `finally` clause.
- If present, the `finally` clause must appear after all of the `catch` clauses.

```
try
{
   (try block statements...)
}
catch (ExceptionType ParameterName)
{
   (catch block statements...)
}
finally
{
   (finally block statements...)
}
```

The `finally` Clause

- The *finally block* is one or more statements,
  - that are always executed after the try block has executed and
  - after any catch blocks have executed if an exception was thrown.
- The statements in the finally block execute whether an exception occurs or not.

The Stack Trace

- The *call stack* is an internal list of all the methods that are currently executing.
- A *stack trace* is a list of all the methods in the call stack.
- It indicates:
  - the method that was executing when an exception occurred and
  - all of the methods that were called in order to execute that method.
- Example: StackTrace.java

Multi-Catch (Java 7)

- Beginning in Java 7, you can specify more than one exception in a `catch` clause:

```
try
{
}
catch(NumberFormatException | InputMismatchException ex)
{
}
```

Separate the exceptions with the `|` character.

Uncaught Exceptions

- When an exception is thrown, it cannot be ignored.
- It must be handled by the program, or by the default exception handler.
- When the code in a method throws an exception:
  - normal execution of that method stops, and
  - the JVM searches for a compatible exception handler inside the method.

Uncaught Exceptions

- If there is no exception handler inside the method:
  - control of the program is passed to the previous method in the call stack.
  - If that method has no exception handler, then control is passed again, up the call stack, to the previous method.
- If control reaches the `main` method:
  - the main method must either handle the exception, or
  - the program is halted and the default exception handler handles the exception.

Checked and Unchecked Exceptions

- There are two categories of exceptions:
  - unchecked
  - checked.
- *Unchecked exceptions* are those that are derived from the `Error` class or the `RuntimeException` class.
- Exceptions derived from `Error` are thrown when a critical error occurs, and should not be handled.
- `RuntimeException` serves as a superclass for exceptions that result from programming errors.

Checked and Unchecked Exceptions

- These exceptions can be avoided with properly written code.
- Unchecked exceptions, in most cases, should not be handled.
- All exceptions that are *not* derived from `Error` or `RuntimeException` are *checked exceptions*.

Checked and Unchecked Exceptions

- If the code in a method can throw a checked exception, the method:
  - must handle the exception, or
  - it must have a `throws` clause listed in the method header.
- The `throws` clause informs the compiler what exceptions can be thrown from a method.

Checked and Unchecked Exceptions

```
// This method will not compile!
public void displayFile(String name)
{
   // Open the file.
   File file = new File(name);
   Scanner inputFile = new Scanner(file);
   // Read and display the file's contents.
   while (inputFile.hasNext())
   {
     System.out.println(inputFile.nextLine());
   }
   // Close the file.
   inputFile.close();
}
```

Checked and Unchecked Exceptions

- The code in this method is capable of throwing checked exceptions.
- The keyword `throws` can be written at the end of the method header, followed by a list of the types of exceptions that the method can throw.

```
public void displayFile(String name)
      throws FileNotFoundException
```

Throwing Exceptions

- You can write code that:
  - throws one of the standard Java exceptions, or
  - an instance of a custom exception class that you have designed.
- The `throw` statement is used to manually throw an exception.

```
throw new ExceptionType(MessageString);
```

- The `throw` statement causes an exception object to be created and thrown.

Throwing Exceptions

- The *MessageString* argument contains a custom error message that can be retrieved from the exception object's `getMessage` method.
- If you do not pass a message to the constructor, the exception will have a null message.

```
throw new Exception("Out of fuel");
```

  - *Note: Don't confuse the* `throw` *statement with the* `throws` *clause.*
- Example: DateComponentExceptionDemo.java

Creating Exception Classes

- You can create your own exception classes by deriving them from the `Exception` class or one of its derived classes.
- Example:
  - BankAccount.java
  - NegativeStartingBalance.java
  - AccountTest.java

Creating Exception Classes

- Some examples of exceptions that can affect a bank account:
  - A negative starting balance is passed to the constructor.
  - A negative interest rate is passed to the constructor.
  - A negative number is passed to the deposit method.
  - A negative number is passed to the withdraw method.
  - The amount passed to the withdraw method exceeds the account's balance.
- We can create exceptions that represent each of these error conditions.

`@exception` Tag in Documentation Comments

- General format

  `@exception` *ExceptionName Description*

- The following rules apply
  - The `@exception` tag in a method's documentation comment must appear after the general description of the method.
  - The description can span several lines. It ends at the end of the documentation comment (the `*/` symbol) or at the beginning of another tag.

Binary Files

- The way data is stored in memory is sometimes called the *raw binary format*.
- Data can be stored in a file in its raw binary format.
- A file that contains binary data is often called a *binary file*.
- Storing data in its binary format is more efficient than storing it as text.
- There are some types of data that should only be stored in its raw binary format.

Binary Files

- Binary files cannot be opened in a text editor such as Notepad.
- To write data to a binary file you must create objects from the following classes:
  - **`FileOutputStream`** - allows you to open a file for writing binary data. It provides only basic functionality for writing bytes to the file.
  - **`DataOutputStream`** - allows you to write data of any primitive type or String objects to a binary file. Cannot directly access a file. It is used in conjunction with a `FileOutputStream` object that has a connection to a file.

Binary Files

- A `DataOutputStream` object is wrapped around a `FileOutputStream` object to write data to a binary file.

```
FileOutputStream fstream = new
      FileOutputStream("MyInfo.dat");
DataOutputStream outputFile = new
      DataOutputStream(fstream);
```

- If the file that you are opening with the `FileOutputStream` object already exists, it will be erased and an empty file by the same name will be created.

Binary Files

- These statements can combined into one.

```
DataOutputStream outputFile = new
  DataOutputStream(new
     FileOutputStream("MyInfo.dat"));
```

- Once the DataOutputStream object has been created, you can use it to write binary data to the file.
- Example: WriteBinaryFile.java

Binary Files

- To open a binary file for input, you wrap a `DataInputStream` object around a `FileInputStream` object.

```
FileInputStream fstream = new
  FileInputStream("MyInfo.dat");
DataInputStream inputFile = new
  DataInputStream(fstream);
```

- These two statements can be combined into one.

```
DataInputStream inputFile = new
  DataInputStream(new
     FileInputStream("MyInfo.dat"));
```

Binary Files

- The `FileInputStream` constructor will throw a `FileNotFoundException` if the file named by the string argument cannot be found.
- Once the `DataInputStream` object has been created, you can use it to read binary data from the file.
- Example:
  - ReadBinaryFile.java

Writing and Reading Strings

- To write a string to a binary file, use the `DataOutputStream` class's `writeUTF` method.
- This method writes its `String` argument in a format known as *UTF-8 encoding*.
  - Just before writing the string, this method writes a two-byte integer indicating the number of bytes that the string occupies.
  - Then, it writes the string's characters in Unicode. (UTF stands for Unicode Text Format.)
- The `DataInputStream` class's `readUTF` method reads from the file.

Writing and Reading Strings

- To write a string to a file:

```
String name = "Chloe";
outputFile.writeUTF(name);
```

- To read a string from a file:

```
String name = inputFile.readUTF();
```

- The `readUTF` method will correctly read a string only when the string was written with the `writeUTF` method.
- Example:
  - WriteUTF.java
  - ReadUTF.java

Appending Data to Binary Files

- The `FileOutputStream` constructor takes an optional second argument which must be a `boolean` value.
- If the argument is `true`, the file will not be erased if it exists; new data will be written to the end of the file.
- If the argument is `false`, the file will be erased if it already exists.

```
FileOutputStream fstream = new
  FileOutputStream("MyInfo.dat", true);
DataOutputStream outputFile = new
  DataOutputStream(fstream);
```

Random Access Files

- Text files and the binary files previously shown use *sequential file access*.
- With sequential access:
  - The first time data is read from the file, the data will be read from its beginning.
  - As the reading continues, the file's read position advances sequentially through the file's contents.
- Sequential file access is useful in many circumstances.
- If the file is very large, locating data buried deep inside it can take a long time.

Random Access Files

- Java allows a program to perform *random file access*.
- In random file access, a program may immediately jump to any location in the file.
- To create and work with random access files in Java, you use the `RandomAccessFile` class.

`RandomAccessFile(String filename, String mode)`

  - *`filename`*: the name of the file.
  - *`mode`*: a string indicating the mode in which you wish to use the file.
    - "r" = reading
    - "rw" = for reading and writing.

Random Access Files

```
// Open a file for random reading.
RandomAccessFile randomFile = new
  RandomAccessFile("MyData.dat", "r");
// Open a file for random reading and writing.
RandomAccessFile randomFile = new
  RandomAccessFile("MyData.dat", "rw");
```

- When opening a file in "r" mode where the file does not exist, a `FileNotFoundException` will be thrown.
- Opening a file in "r" mode and trying to write to it will throw an `IOException`.
- If you open an existing file in "rw" mode, it will not be deleted and the file's existing content will be preserved.

Random Access Files

- Items in a sequential access file are accessed one after the other.
- Items in a random access file are accessed in any order.
- If you open a file in "rw" mode and the file does not exist, it will be created.
- A file that is opened or created with the `RandomAccessFile` class is treated as a binary file.

Random Access Files

- The `RandomAccessFile` class has:
  - the same methods as the `DataOutputStream` class for writing data, and
  - the same methods as the `DataInputStream` class for reading data.
- The `RandomAccessFile` class can be used to sequentially process a binary file.
- Example: WriteLetters.java

The File Pointer

- The `RandomAccessFile` class treats a file as a stream of bytes.
- The bytes are numbered:
  - the first byte is byte 0.
  - The last byte's number is one less than the number of bytes in the file.
- These byte numbers are similar to an array's subscripts, and are used to identify locations in the file.
- Internally, the `RandomAccessFile` class keeps a long integer value known as the *file pointer*.

The File Pointer

- The *file pointer* holds the byte number of a location in the file.
- When a file is first opened, the file pointer is set to 0.
- When an item is read from the file, it is read from the byte that the file pointer points to.
- Reading also causes the file pointer to advance to the byte just beyond the item that was read.
- If another item is immediately read, the reading will begin at that point in the file.

The File Pointer

- An `EOFException` is thrown when a read causes the file pointer to go beyond the size of the file.
- Writing also takes place at the location pointed to by the file pointer.
- If the file pointer points to the end of the file, data will be written to the end of the file.
- If the file pointer holds the number of a byte within the file, at a location where data is already stored, a write will overwrite the data at that point.

The File Pointer

- The `RandomAccessFile` class lets you move the file pointer.
- This allows data to be read and written at any byte location in the file.
- The seek method is used to move the file pointer.

```
rndFile.seek(long position);
```

- The argument is the number of the byte that you want to move the file pointer to.

The File Pointer

```
RandomAccessFile file = new
  RandomAccessFile("MyInfo.dat", "r");
file.seek(99);
byte b = file.readByte();
```

- Example: ReadRandomLetters.java

Object Serialization

- If an object contains other types of objects as fields, saving its contents can be complicated.
- Java allows you to *serialize* objects, which is a simpler way of saving objects to a file.
- When an object is serialized, it is converted into a series of bytes that contain the object's data.
- If the object is set up properly, even the other objects that it might contain as fields are automatically serialized.
- The resulting set of bytes can be saved to a file for later retrieval.

Object Serialization

- For an object to be serialized, its class must implement the `Serializable` interface.
- The `Serializable` interface has no methods or fields.
- It is used only to let the Java compiler know that objects of the class might be serialized.
- If a class contains objects of other classes as fields, those classes must also implement the `Serializable` interface, in order to be serialized.
- Example: BankAccount2.java

Object Serialization

- The `String` class, as many others in the Java API, implements the `Serializable` interface.
- To write a serialized object to a file, you use an `ObjectOutputStream` object.
- The `ObjectOutputStream` class is designed to perform the serialization process.
- To write the bytes to a file, an output stream object is needed.

```
FileOutputStream outStream = new
  FileOutputStream("Objects.dat");
ObjectOutputStream objectOutputFile = new
  ObjectOutputStream(outStream);
```

Object Serialization

- To serialize an object and write it to the file, the `ObjectOutputStream` class's `writeObject` method is used.

```
BankAccount2 account = new
        BankAccount(25000.0);
objectOutputFile.writeObject(account);
```

- The `writeObject` method throws an `IOException` if an error occurs.
- The process of reading a serialized object's bytes and constructing an object from them is known as *deserialization*.

Object Serialization

- To deserialize an object an `ObjectInputStream` object is used in conjunction with a `FileInputStream` object.

```
FileInputStream inStream = new
  FileInputStream("Objects.dat");
ObjectInputStream objectInputFile = new
  ObjectInputStream(inStream);
```

- To read a serialized object from the file, the `ObjectInputStream` class's `readObject` method is used.

```
BankAccount2 account;
account = (BankAccount2)
  objectInputFile.readObject();
```

Object Serialization

- The `readObject` method returns the deserialized object.
  - *Notice that you must cast the return value to the desired class type.*
- The `readObject` method throws a number of different exceptions if an error occurs.
- Examples:
  - SerializeObjects.java
  - DeserializeObjects.java