

Topic 5

Exceptions and File I/O

"A slipping gear could let your M203 grenade launcher fire when you least expect it. That would make you quite unpopular in what's left of your unit."

- *THE U.S. Army's PS magazine, August 1993, quoted in The Java Programming Language, 3rd edition*

When Good Programs Go Bad

- ▶ A variety of errors can occur when a program is running. For example:
 - (real) user input error. bad url
 - device errors. remote server unavailable
 - physical limitations. full disk
 - code errors. interact with code that does not fulfill its contract (pre and post conditions)
- ▶ when an error occurs
 - return to safe state, save work, exit gracefully
- ▶ error handling code may be far removed from code that caused the error

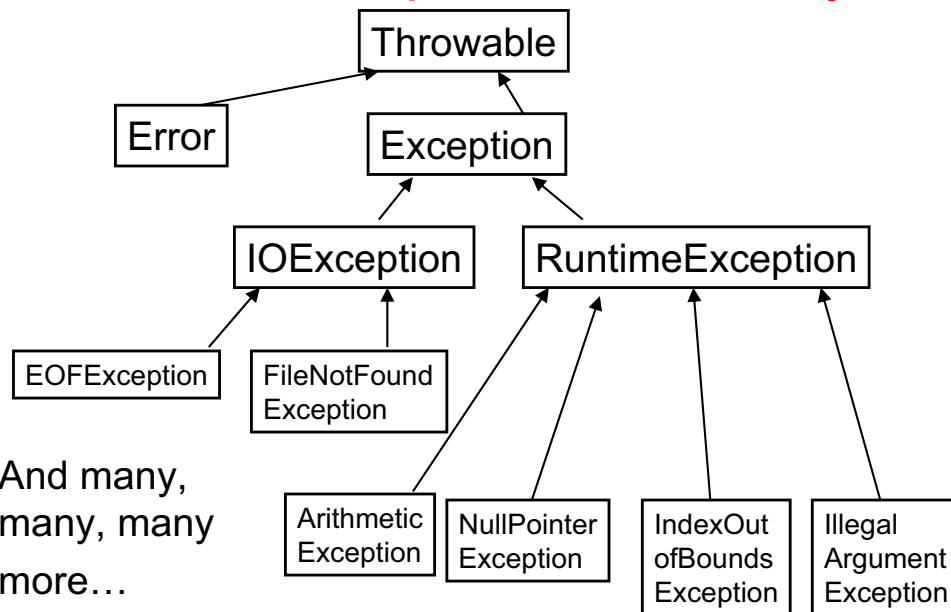
How to Handle Errors?

- ▶ It is possible to detect and handle errors of various types.
- ▶ Problem: this complicates the code and makes it harder to understand.
 - the error detection and error handling code have little or nothing to do with the *real* code is trying to do.
- ▶ A tradeoff between ensuring correct behavior under all possible circumstances and clarity of the code

Exceptions

- ▶ Many languages, including Java use a mechanism known as *Exceptions* to handle errors at runtime
 - In Java Exception is a class with many descendants.
 - **ArrayIndexOutOfBoundsException**
 - **NullPointerException**
 - **FileNotFoundException**
 - **ArithmeticException**
 - **IllegalArgumentException**

Partial Exceptions Hierarchy



And many,
many, many
more...

Creating Exceptions

- ▶ As a program runs, if a situation occurs that is handled by exceptions then an Exception is *thrown*.
 - An Exception object of the proper type is created
 - flow of control is transferred from the current block of code to code that can handle or deal with the exception
 - the normal flow of the program stops and error handling code takes over (if it exists.)

Unchecked Exceptions

- ▶ Exceptions in Java fall into two different categories
 - *checked (other than Runtime) and unchecked (Runtime)*
- ▶ unchecked exceptions are **completely preventable** and should never occur.
 - They are caused by logic errors, created by us, the programmers.
- ▶ Descendents of the RuntimeException class
- ▶ Examples: ArrayIndexOutOfBoundsException, NullPointerException, ArithmeticException
- ▶ There does not *need* to be special error handling code
 - just regular error prevention code
- ▶ If error handling code was required programs would be unwieldy because so many Java statements have the possibility of generating or causing an unchecked Exception

Checked Exceptions

- ▶ "Checked exceptions represent conditions that, although exceptional, can reasonably be expected to occur, and if they do occur must be dealt with in some way.[other than the program terminating.]"
 - *Java Programming Language third edition*
- ▶ Unchecked exceptions are due to a programming logic error, our fault and preventable if coded correctly.
- ▶ Checked exceptions represent errors that are unpreventable by us!

Required Error Handling Code

- ▶ If you call a method that can generate a checked exception you must choose how to deal with that possible error
- ▶ For example one class for reading from files is the `FileReader` class

```
public FileReader(String fileName)  
    throws FileNotFoundException
```

- ▶ This constructor has the possibility of throwing a `FileNotFoundException`
- ▶ `FileNotFoundException` is a checked exception

Checked Exceptions in Code

- ▶ If we have code that tries to build a `FileReader` we must deal with the possibility of the exception

```
import java.io.FileReader;  
  
public class Tester  
{  
    public int countChars(String fileName)  
    {  
        FileReader r = new FileReader(fileName);  
        int total = 0;  
        while( r.ready() )  
        {  
            r.read();  
            total++;  
        }  
        r.close();  
        return total;  
    }  
}
```

- ▶ The code contains a syntax error. "unreported exception `java.io.FileNotFoundException`; must be caught or declared to be thrown."

Handling Checked Exceptions

- ▶ In the code on the previous slide there are in fact 4 statements that can generate checked exceptions.
 - The `FileReader` constructor
 - the `ready` method
 - the `read` method
 - the `close` method
- ▶ To deal with the exceptions we can either state this method throws an Exception of the proper type or handle the exception within the method itself

Methods that throw Exceptions

- ▶ It may be that we don't know how to deal with an error within the method that can generate it
- ▶ In this case we will pass the buck to the method that called us
- ▶ The keyword `throws` is used to indicate a method has the possibility of generating an exception of the stated type
- ▶ Now any method calling ours must also throw an exception or handle it

Using the `throws` Keyword

```
public int countChars(String fileName)
    throws FileNotFoundException, IOException
{
    int total = 0;
    FileReader r = new FileReader(fileName);
    while( r.ready() )
    {
        r.read();
        total++;
    }
    r.close();
    return total;
}
```

- ▶ Now any method calling ours must also throw an exception or handle it

Using `try-catch` Blocks

- ▶ If you want to handle the a checked exception locally then use use the keywords `try` and `catch`
- ▶ the code that could cause an exception is placed in a block of code preceded by the keyword `try`
- ▶ the code that will handle the exception if it occurs is placed in a block of code preceded by the keyword `catch`

Sample `try` and `catch` Blocks

```
public int countChars(String fileName)
{
    int total = 0;
    try
    {
        FileReader r = new FileReader(fileName);
        while( r.ready() )
        {
            r.read();
            total++;
        }
        r.close();
    }
    catch(FileNotFoundException e)
    {
        System.out.println("File named "
            + fileName + "not found. " + e);
        total = -1;
    }
    catch(IOException e)
    {
        System.out.println("IOException occurred " +
            "while counting chars. " + e);
        total = -1;
    }
    return total;
}
```

Mechanics of `try` and `catch`

- ▶ Code that could cause the checked exception is placed in a `try` block
 - note how the statements are included in one `try` block.
 - Each statement could be in a separate `try` block with an associated `catch` block, but that is very unwieldy (see next slide)
- ▶ Each `try` block must have 1 or more associated `catch` blocks
 - code here to handle the error. In this case we just print out the error and set result to -1

Gacky try catch Block

```
public int countChars3(String fileName)
{
    int total = 0;
    FileReader r = null;
    try
    {
        r = new FileReader(fileName);
    }
    catch(FileNotFoundException e)
    {
        System.out.println("File named "
            + fileName + "not found. " + e);
        total = -1;
    }

    try
    {
        while( r.ready() )
        {
            try
            {
                r.read();
            }
            catch(IOException e)
            {
                System.out.println("IOException "
                    + "occurred while counting "
                    + "chars. " + e);
                total = -1;
            }
            total++;
        }
    }
    catch(IOException e)
    {
        System.out.println("IOException occurred while counting chars. " + e);
        total = -1;
    }
    try
    {
        r.close();
    }
    catch(IOException e)
    {
        System.out.println("IOException occurred while counting chars. " + e);
        total = -1;
    }
    return total;
}
```

More try catch Mechanics

- ▶ If you decide to handle the possible exception locally in a method with the try block you must have a corresponding catch block
- ▶ the catch blocks have a parameter list of 1
- ▶ the parameter must be Exception or a descendant of Exception
- ▶ Use multiple catch blocks with one try block in case of multiple types of Exceptions

What Happens When Exceptions Occur

- ▶ If an exception is thrown then the normal flow of control of a program halts
- ▶ Instead of executing the regular statements the Java Runtime System starts to search for a matching catch block
- ▶ The first matching catch block based on data type is executed
- ▶ When the catch block code is completed the program does not "go back" to where the exception occurred.
 - It finds the next regular statement after the catch block

Counting Chars Again

```
public int countChars(String fileName)
{
    int total = 0;
    try
    {
        FileReader r = new FileReader(fileName);
        while( r.ready() )
        {
            r.read();// what happens in an exception occurs?
            total++;
        }
        r.close();
    }
    catch(FileNotFoundException e)
    {
        System.out.println("File named "
            + fileName + "not found. " + e);
        total = -1;
    }
    catch(IOException e)
    {
        System.out.println("IOException occured " +
            "while counting chars. " + e);
        total = -1;
    }
    return total;
}
```

Throwing Exceptions Yourself

- ▶ if you wish to throw an exception in your code you use the `throw` keyword
- ▶ Most common would be for an unmet precondition

```
public class Circle
{
    private int iMyRadius;

    /** pre: radius > 0
     */
    public Circle(int radius)
    {
        if (radius <= 0)
            throw new IllegalArgumentException
                ("radius must be > 0. "
                 + "Value of radius: " + radius);
        iMyRadius = radius;
    }
}
```

Error Handling, Error Handling Everywhere!

- ▶ Seems like a lot of choices for error prevention and error handling
 - normal program logic, e.g. if's for loop counters
 - assertions
 - try – catch block
- ▶ When is it appropriate to use each kind?

Error Prevention

- ▶ Us program logic, (ifs , fors) to prevent logic errors and unchecked exceptions
 - dereferencing a null pointer, going outside the bounds of an array, violating the preconditions of a method you are calling. e.g. the `charAt` method of the `String` class
 - use assertions as checks on your logic
 - you checked to ensure the variable `index` was within the array bounds with an if 10 lines up in the program and you are SURE you didn't alter it.
 - Use an `assert` right before you actually access the array

Error Prevention

- ▶ in 307 asserts can be used to check preconditions
 - Standard Java style is to use Exceptions
- ▶ Use try/catch blocks on checked exceptions
 - In general, don't use them to handle unchecked exceptions like NPE or AIOBE
- ▶ One place it is reasonable to use try / catch is in testing suites.
 - put each test in a try / catch. If an exception occurs that test fails, but other tests can still be run

File Input and Output

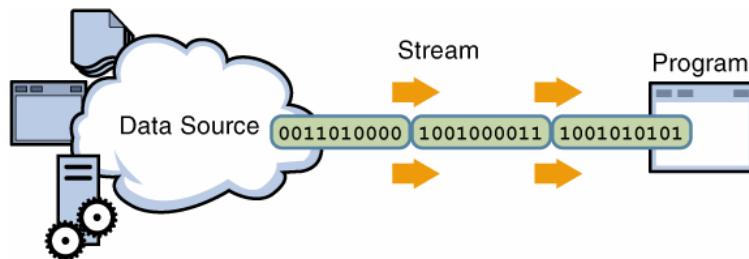
- ▶ Programs must often read from and write to files
 - large amounts of data
 - data not known at runtime
 - data that changes over time
- ▶ Each programming language has its own way of handling input and output
 - involves dealing with the operating system
 - if possible try to hide that fact as much as possible
- ▶ Java attempts to standardize input and output with the notion of a *stream*, an ordered sequence of data that has a source or destination.

Streams?

Dr. Egon Spengler: Don't cross the streams.
Dr. Peter Venkman: Why not?
Dr. Egon Spengler: It would be bad.
Dr. Peter Venkman: I'm fuzzy on the whole good/bad thing, what do you mean by "bad"?
Dr. Egon Spengler: Try to imagine all life as you know it stopping instantaneously and every molecule in your body exploding at the speed of light.
Dr. Peter Venkman: That's bad. Okay. Alright, important safety tip. Thanks Egon.

Streams

- ▶ A stream serves as a connection between your program and an external source or destination for bytes and bits
 - could be standard input or output, files, network connections, or other programs



Lots of Streams

- ▶ Java has over sixty (60!) different stream types in its java.io package
- ▶ part of the reason input and output are so difficult to understand in Java is the size and diversity of the IO library
- ▶ The type of stream you use depends on what you are trying to do
 - even then there are multiple options

Working with Files in Java

- ▶ Data is stored in digital form, 1s and 0s
- ▶ Work with these in packages of 8, the byte
- ▶ The IO library creates higher level abstractions so we think we are working with characters, Strings, or whole objects
- ▶ Some abstract classes
 - InputStream, OutputStream, Reader, and Writer
 - InputStream and OutputStream represent the flow of data (a stream)
 - Reader and Writer are used to read the data from a stream or put the data in a stream
 - *convenience classes* exist to make things a little easier

The Scanner class

- ▶ A class to make reading from source of input easier. New in Java 5.0
- ▶ Constructors
 - Scanner(InputStream)
 - Scanner(File)
- ▶ Methods to read lines from input
 - boolean hasNextLine()
 - String nextLine()
- ▶ Methods to read ints
 - int readInt(), boolean hasNext()

Scanner and Keyboard Input

- ▶ No exceptions thrown!
 - no try – catch block necessary!
- ▶ Set delimiters with regular expressions, default is whitespace

```
Scanner s = new Scanner(System.in);
```

```
System.out.print("Enter your name: ");  
String name = s.nextLine();
```

```
System.out.print("Press Enter to continue: ");  
s.nextLine();
```

Hooking a Scanner up to a File

```
import java.util.Scanner;  
import java.io.File;  
import java.io.IOException;  
  
public class ReadAndPrintScores  
{  
    public static void main(String[] args)  
    {  
        try  
        {  
            Scanner s = new Scanner( new File("scores.dat") );  
            while( s.hasNextInt() )  
            {  
                System.out.println( s.nextInt() );  
            }  
            s.close();  
        }  
        catch(IOException e)  
        {  
            System.out.println( e );  
        }  
    }  
}
```

```
12 35 12  
12 45  
12  
  
12  
  
13 57
```

scores.dat

Writing to a File

```
//sample code to write 100 random ints to a file, 1 per line

import java.io.PrintStream;
import java.io.IOException;
import java.io.File;

import java.util.Random;

public class WriteToFile
{
    public static void main(String[] args)
    {
        try
        {
            PrintStream writer = new PrintStream( new
                File("randInts.txt"));
            Random r = new Random();
            final int LIMIT = 100;

            for(int i = 0; i < LIMIT; i++)
            {
                writer.println( r.nextInt() );
            }
            writer.close();
        }
        catch(IOException e)
        {
            System.out.println("An error occurred " +
                + "while trying to write to the file");
        }
    }
}
```