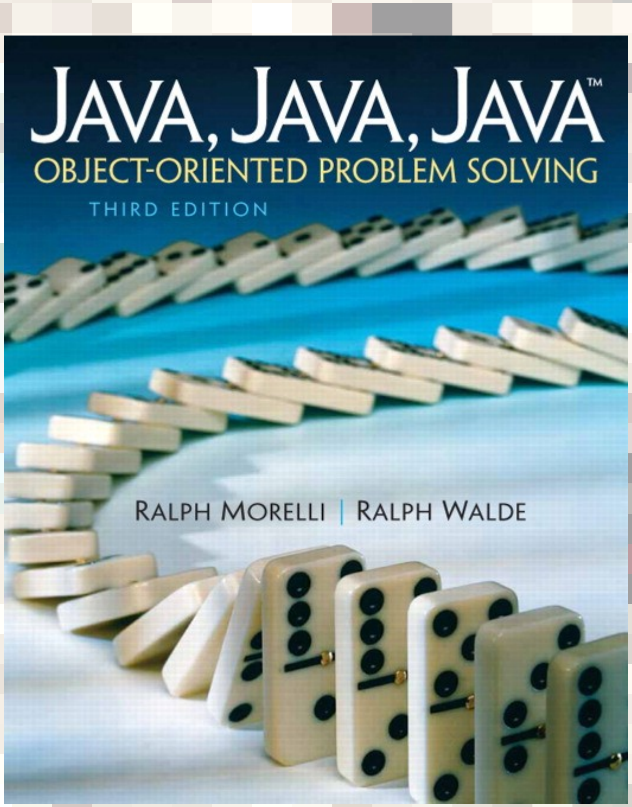

presentation slides for

JAVA, JAVA, JAVA

Object-Oriented Problem Solving

Third Edition

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published by Prentice Hall

Java, Java, Java

Object Oriented Problem Solving

Lecture 3: Exceptions

Objectives

- Understand Java's exception handling mechanisms.
- Be able to use the Java try/catch statement.
- Know how to design effective exception handlers.
- Appreciate the importance that exception handling plays in program design.
- Be able to design your own Exception subclasses.

Outline

- Introduction
- Handling Exceptional Conditions
- Java’s Exception Hierarchy
- Handling Exceptions within a Program
- Error Handling and Robust Program Design
- Creating and Throwing Your Own Exceptions

Introduction

- No matter how well designed a program is, there is always the chance that error will arise during its execution.
- A well-designed program should include code to handle errors and other exceptional conditions when they arise.
- This chapter describes Java's exception handling features.

Introduction

- An **exception** is a problem that arises during the execution of a program.
- When an Exception occurs the normal flow of the program is disrupted, and the program/application terminates abnormally.
- Therefore, these exceptions are to be handled.

Handling Exceptional Conditions

- The avgFirstN() method expects that $N > 0$.
- If $N = 0$, a *divide-by-zero* error occurs in *avg/N*.

```java
/**
  * Precondition:  N > 0
  * Postcondition: avgFirstN() equals the average of (1+2+…+N)
  */
public double avgFirstN(int N) {
    double sum = 0;
    for (int k = 1; k <= N; k++)
        sum += k;
    return sum/N;      // What if N is 0 ??
} // avgFirstN()
```

Bad Design: Doesn’t guard against divide-by-0.

Traditional Error Handling

- Error-handling code built right into the algorithm:

```
/**
  * Precondition:  N > 0
  * Postcondition: avgFirstN() equals the average of (1+2+…+N)
  */
public double avgFirstN(int N) {
   double sum = 0;
   if (N <= 0) {
     System.out.println(“ERROR avgFirstN: N <= 0. Program
terminating.”);
     System.exit(0);
   }
   for (int k = 1; k <= N; k++)
      sum += k;
   return sum/N;       // What if N is 0 ??
} // avgFirstN()
```

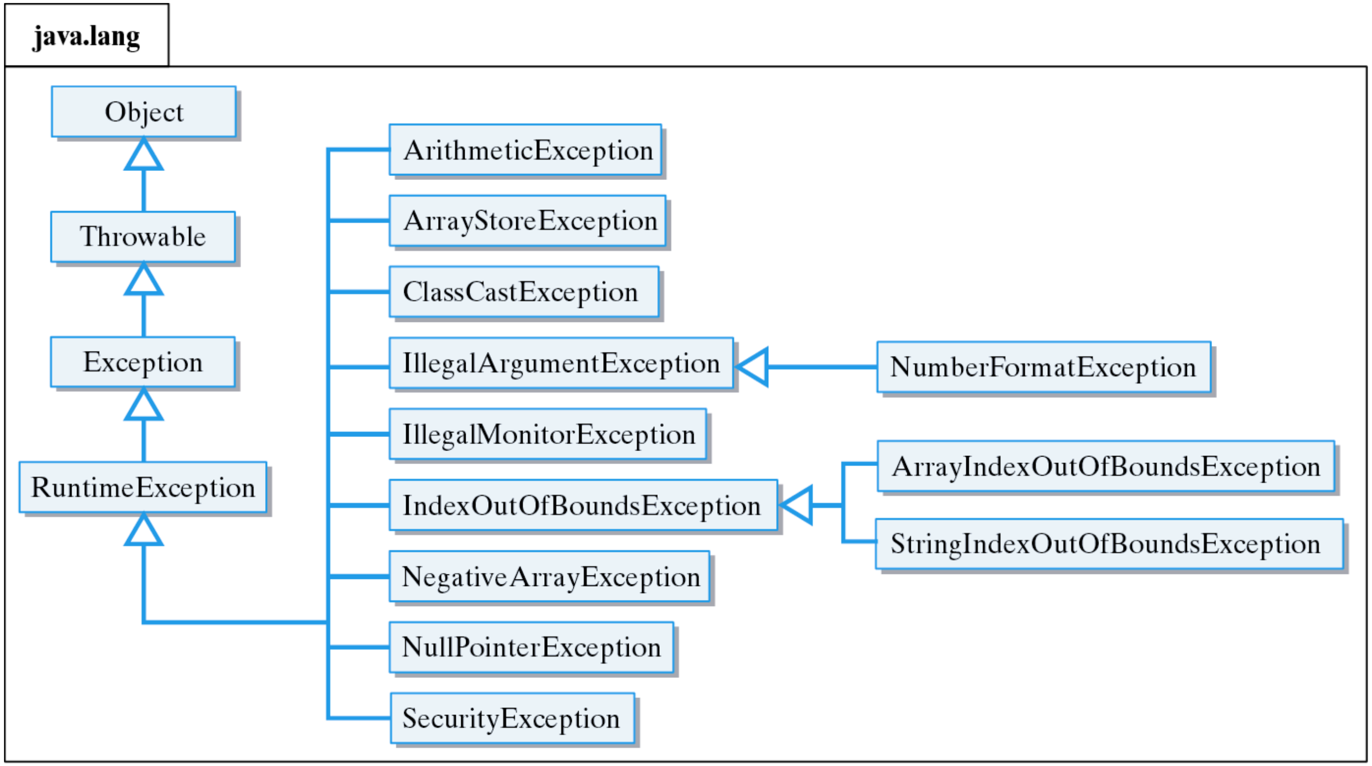
It’s sometimes risky to exit a program like this.

Type of Exceptions

- There are two types of exceptions in Java:
  - Checked (compile time) exceptions
  - Unchecked (runtime) exceptions.

Java's Exception Hierarchy

- *Unchecked exceptions* belong to a subclass of RuntimeException and are not monitored by the compiler.



Some Important Exceptions

Class	Description
ArithmeticException	Division by zero or some other kind of arithmetic problem
ArrayIndexOutOfBounds-Exception	An array index is less than zero or greater than or equal to the array's length
FileNotFoundException	Reference to an unfound file
IllegalArgumentException	Method call with improper argument
IndexOutOfBoundsException	An array or string index out of bounds
NullPointerException	Reference to an object which has not been instantiated
NumberFormatException	Use of an illegal number format, such as when calling a method
StringIndexOutOfBoundsException	A String index less than zero or greater than or equal to the String's length

Some Common Exceptions

Class	Method	Exception Raised	Description
Double	valueOf(String)	NumberFormatException	The String is not a double
Integer	parseInt(String)	NumberFormatException	The String is not a int
String	String(String)	NullPointerException	The String is null
	indexOf(String)	NullPointerException	The String is null
	lastIndexOf(String)	NullPointerException	The String is null
	charAt(int)	StringIndexOutOfBoundsException	The int is invalid index
	substring(int)	StringIndexOutOfBoundsException	The int is invalid index
	substring(int,int)	StringIndexOutOfBoundsException	An int is invalid index

Checked Exceptions

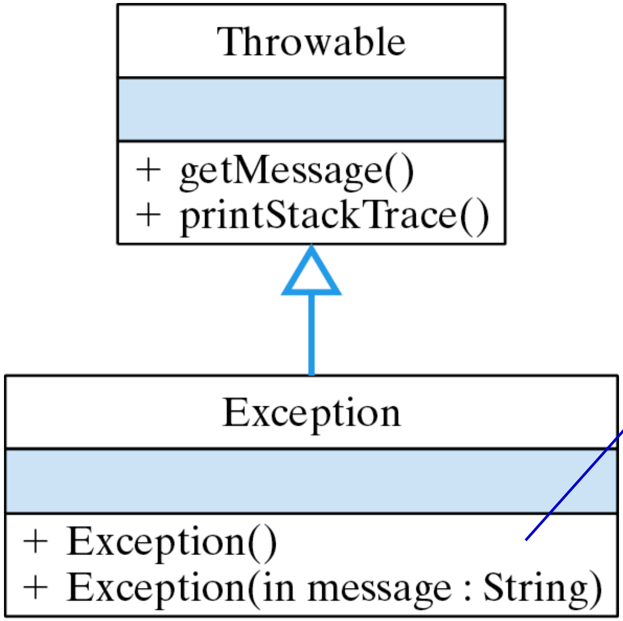
- *Checked exception* *must* either be caught or declared within the method where it is thrown.
- Monitored by the Java compiler.
- Example: IOException

IOException must be declared ...

```
public static void main(String argv[]) throws IOException {

   BufferedReader input = new BufferedReader
           (new InputStreamReader(System.in));

   String inputString = input.readLine();     // May throw IOException
}
```

...because readLine() may cause it.

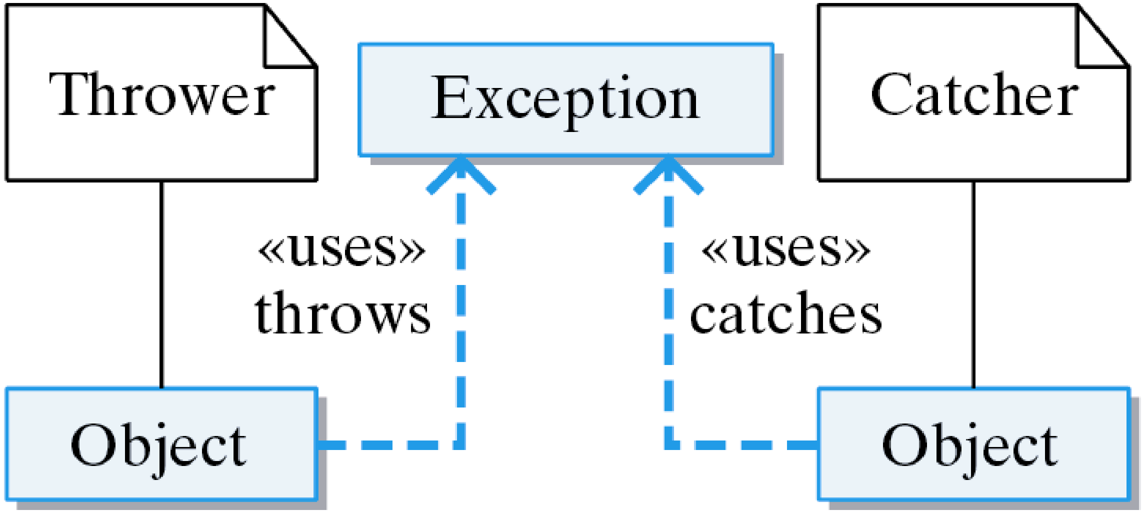
The Exception Class



Simple: only constructor methods.

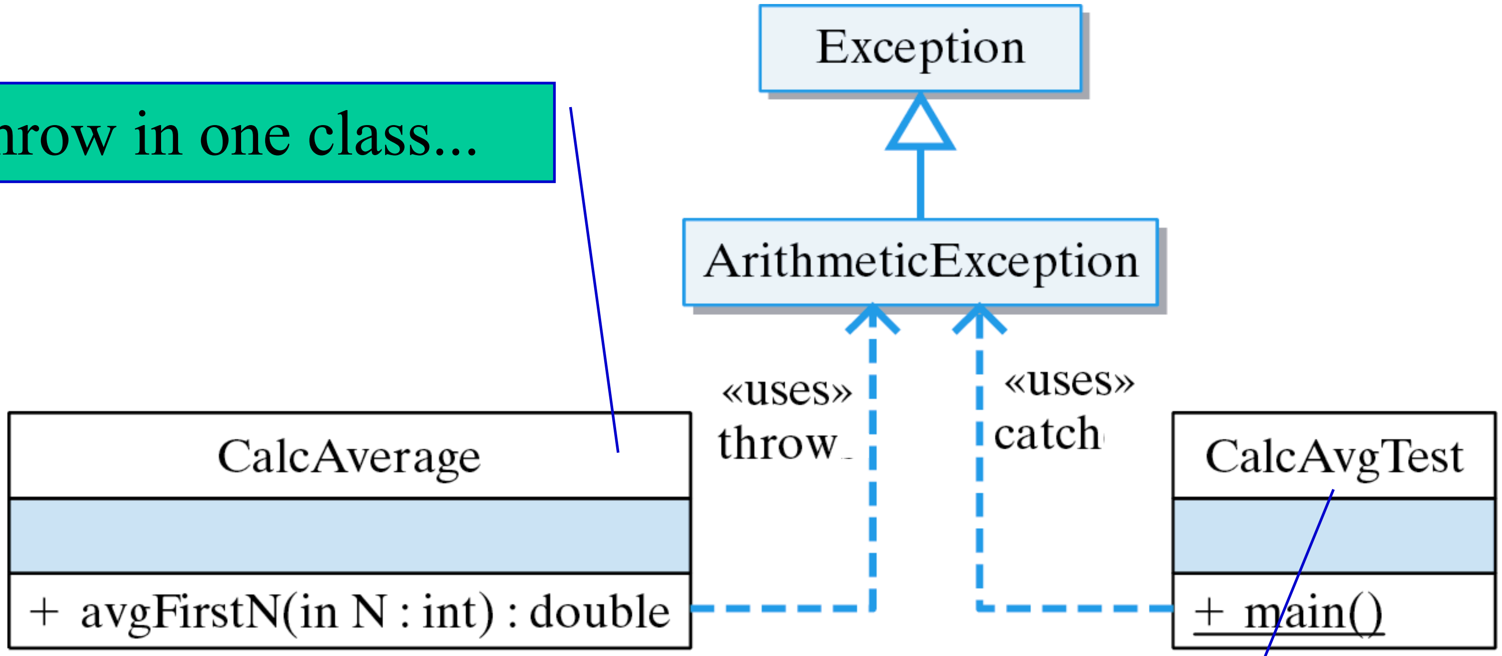
Exception Handling

- When an exception occurs, an object will throw an exception. The *exception handler,* possibly the same object, will catch it.
- Use keywords "**try**", "throw", "**catch**", "finally".



Example: Two Classes

Throw in one class...



…Catch in the other class.

Try, Throw and Catch

```
public class CalcAverage {
  public double avgFirstN(int N ) {
    double sum = 0;
    if (N <= 0)
       throw new ArithmeticException("ERROR: Can't average 0 elements");
    for (int k = 1; k <= N; k++)
       sum += k;
    return sum/N;
  }// avgFirstN()
} // CalcAverage

public class CalcAvgTest {
  public static void main(String args[]) {
    try {
      CalcAverage ca = new CalcAverage();
      System.out.println(“AVG + ” + ca.avgFirstN(0));
    } catch (ArithmeticException e) { // Catch block: exception handler
       System.out.println(e.getMessage());
       e.printStackTrace();
       System.exit(0);
    }
  }// main()
} // CalcAvgTest
```

Throw in one class...

...Catch in the other.

Effective Design: Java’s exception handling mechanism allows you to separate normal code from exception handling code.

Try/Throw/Catch

- A *try block* contains statements that may cause an exception. It signals your intention to handle the exception.
- Throwing an exception is like pulling the fire alarm. Once an exception is thrown, control is transferred to an appropriate catch clause.
- Exceptions are handled in the *catch clause*.
- The *finally block* is optional. Unless the program is exited, it is executed whether an exception is thrown or not.

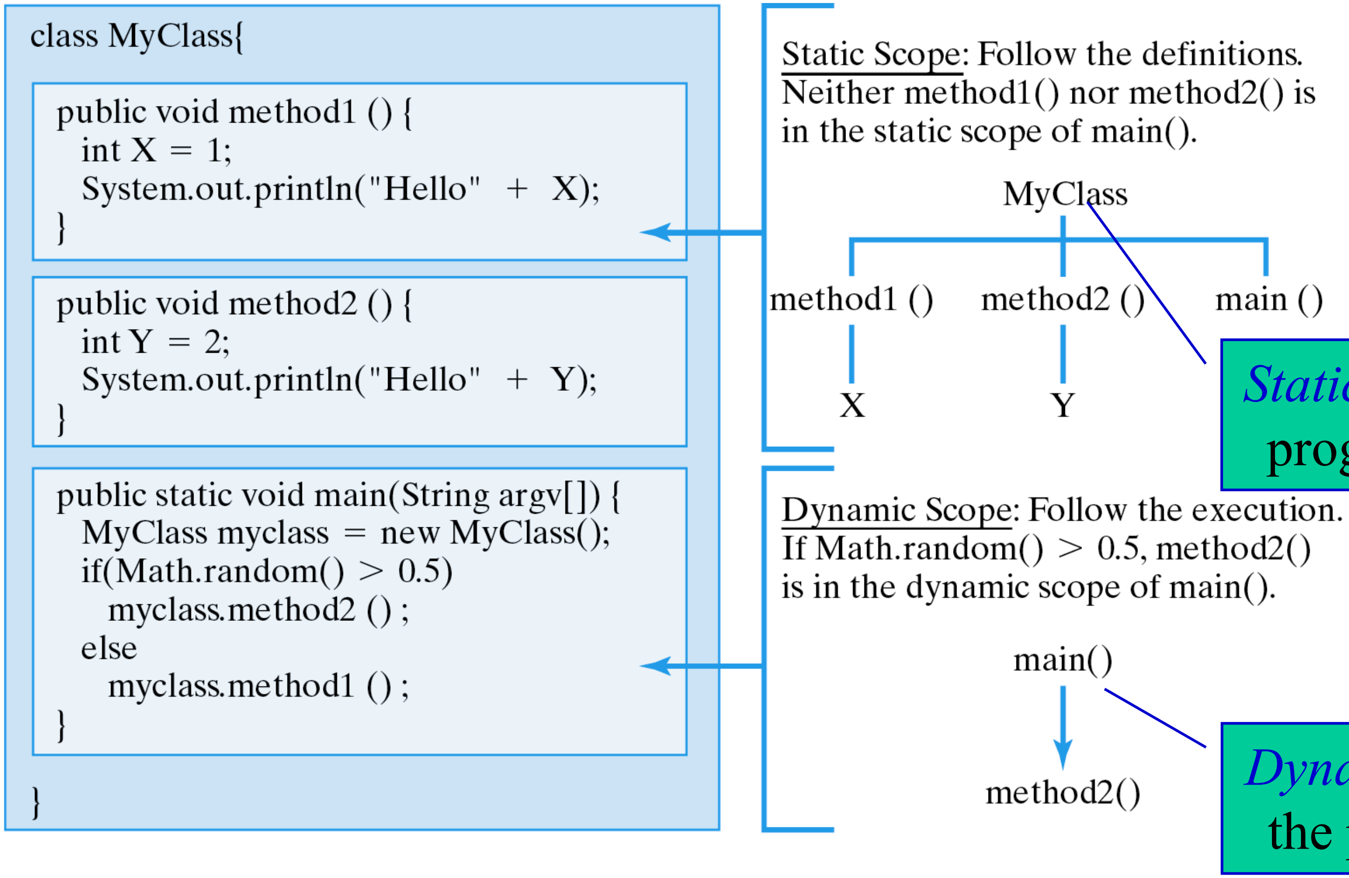
Multiple Handlers

```
try {
    // Block of statements
    // At least one of which may throw an exception

    if ( /* Some condition obtains */ )
       throw new ExceptionName();

} catch (ExceptionName ParameterName) {
    // Block of statements to be executed
    // If the ExceptionName exception is thrown in try
}
...  // Possibly other catch clauses
}  catch (ExceptionName2 ParameterName) {
    // Block of statements to be executed
    // If the ExceptionName2 exception is thrown in try
} finally {
    // Optional block of statements that is executed
    // Whether an exception is thrown or not
}
```

Restrictions on try/catch/finally

- A try block must be followed by one or more catch clauses.
- A catch clause may only follow a try block.
- A throw statement is used to throw both *checked* and *unchecked* exceptions.
- Unchecked exceptions belong to RuntimeException or its subclasses.
- Checked exceptions must be caught or declared.
- A throw statement must be contained within the *dynamic scope* of a try block, and the type of Exception thrown must match at least one of the try block's catch clauses.

Dynamic versus Static Scope



```
class MyClass{
  public void method1 () {
    int X = 1;
    System.out.println("Hello"  +  X);
  }
  public void method2 () {
    int Y = 2;
    System.out.println("Hello"  +  Y);
  }
  public static void main(String argv[]) {
    MyClass myclass = new MyClass();
    if(Math.random() > 0.5)
      myclass.method2 () ;
    else
      myclass.method1 () ;
  }
}
```

Static Scope: Follow the definitions. Neither method1() nor method2() is in the static scope of main().

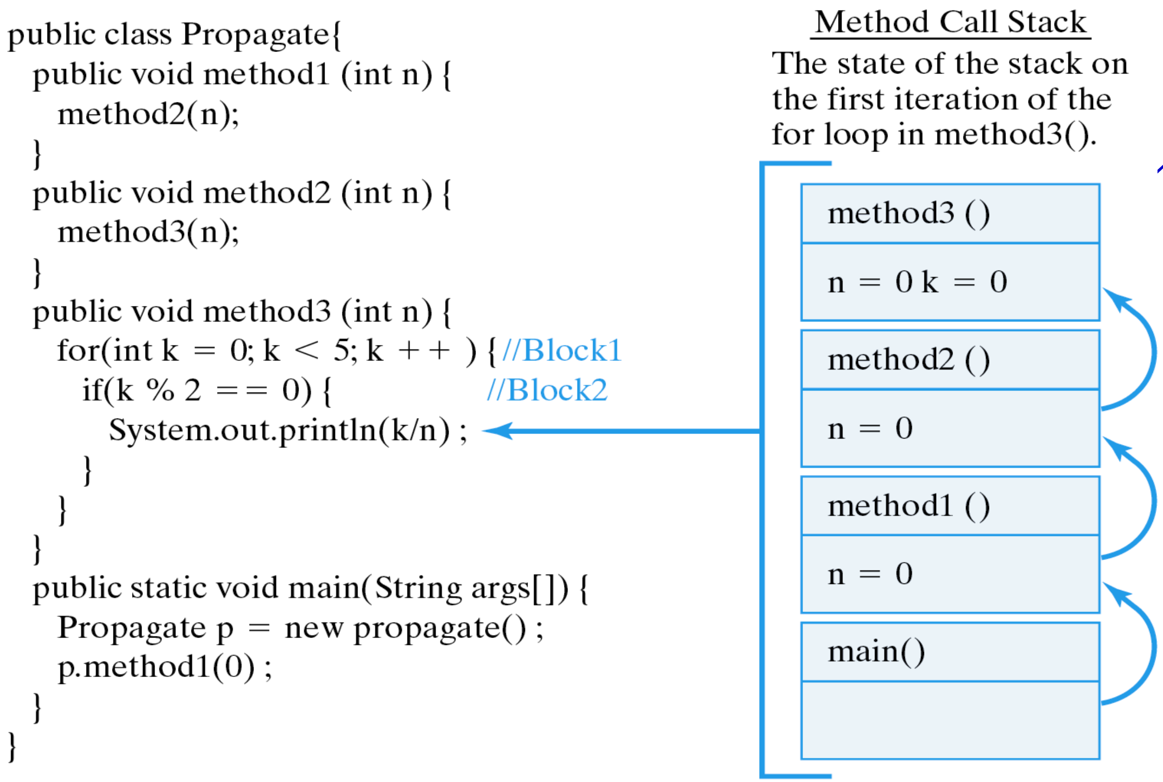
Dynamic Scope: Follow the execution. If Math.random() > 0.5, method2() is in the dynamic scope of main().

Static scope: how the program is written.

Dynamic scope: how the program is run.

The Method Call Stack

- The *method call stack* keeps track of the methods that are called during program execution. The current method is on the top of the stack.



```
public class Propagate{
  public void method1 (int n) {
    method2(n);
  }
  public void method2 (int n) {
    method3(n);
  }
  public void method3 (int n) {
    for(int k = 0; k < 5; k ++ ) {//Block1
      if(k % 2 == 0) {            //Block2
        System.out.println(k/n) ;
      }
    }
  }
  public static void main(String args[]) {
    Propagate p = new propagate() ;
    p.method1(0) ;
  }
}
```

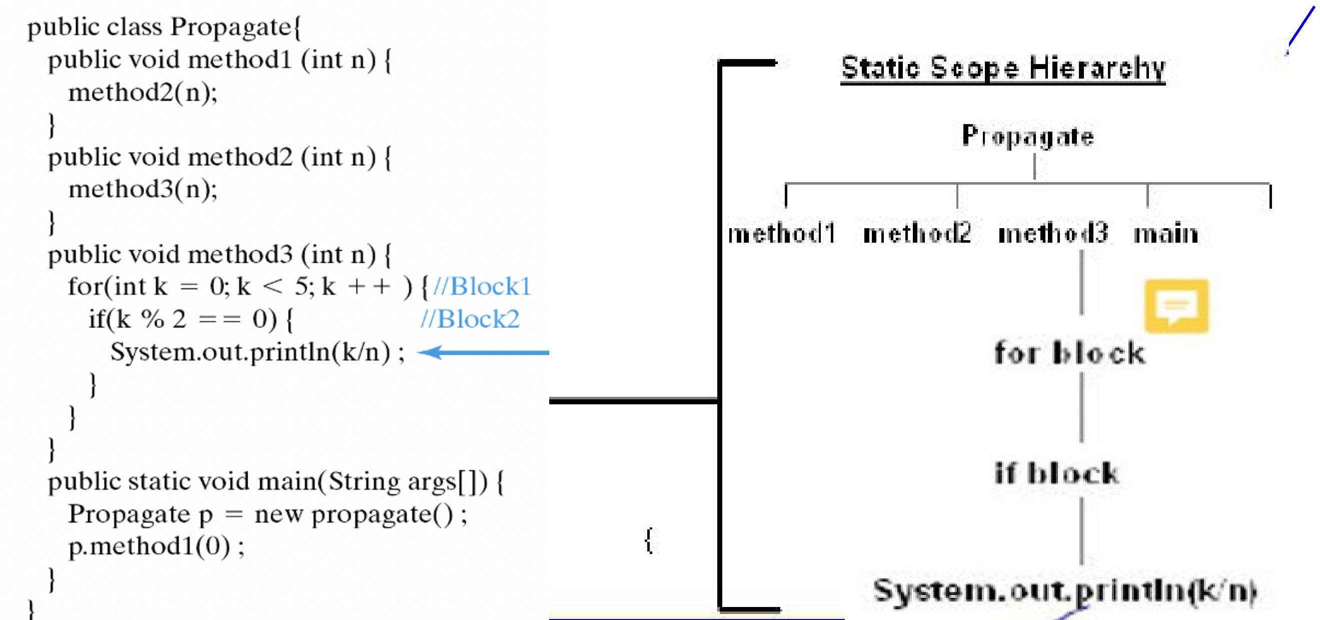
Method Call Stack

The state of the stack on the first iteration of the for loop in method3().

Dynamic scope: main() calls method1() which calls method2() which calls method3().

Finding a Catch Block

- Search upward through the static scope and backward through the dynamic scope.



```
public class Propagate{
  public void method1 (int n) {
    method2(n);
  }
  public void method2 (int n) {
    method3(n);
  }
  public void method3 (int n) {
    for(int k = 0; k < 5; k ++ ) {//Block1
      if(k % 2 == 0) {           //Block2
        System.out.println(k/n) ;
      }
    }
  }
  public static void main(String args[]) {
    Propagate p = new propagate() ;
    p.method1(0) ;
  }
}
}
```

Static scope: If an error occurs in *k/n*, Java searches up this branch for an exception handler.

Dynamic scope: If no handler found in method3() Java searches method2(), then method1(), then main().

Default Exception Handling

- Java can handle unchecked exceptions itself.

```
public class CalcAverage {
  public double avgFirstN(int N ) {
    double sum = 0;
    if (N <= 0)
       throw new ArithmeticException("ERROR: Can't average 0
elements");
    for (int k = 1; k <= N; k++)
       sum += k;
    return sum/N;
  } // avgFirstN()

  public static void main(String args[]) {
      CalcAverage ca = new CalcAverage();
      System.out.println( "AVG: " + ca.avgFirstN(0));
  } // main()
} // CalcAverage
```

No catch clause for ArithmeticException, so Java handles the exception itself.

```
java.lang.ArithmeticException: ERROR: Can't average 0 elements
       at CalcAverage.avgFirstN(CalcAverage.java:9)
       at CalcAverage.main(CalcAverage.java:20)
       at com.mw.Exec.run(JavaAppRunner.java:47)
```

Robust Program Design

- Four ways to handle exceptions:

Kind of Exception	Kind of Program	Action to be Taken
Caught by Java		Let Java handle it
Fixable condition		Fix the error and resume execution
Unfixable condition	Stoppable	Report error and terminate
Unfixable condition	Not stoppable	Report error and resume processing

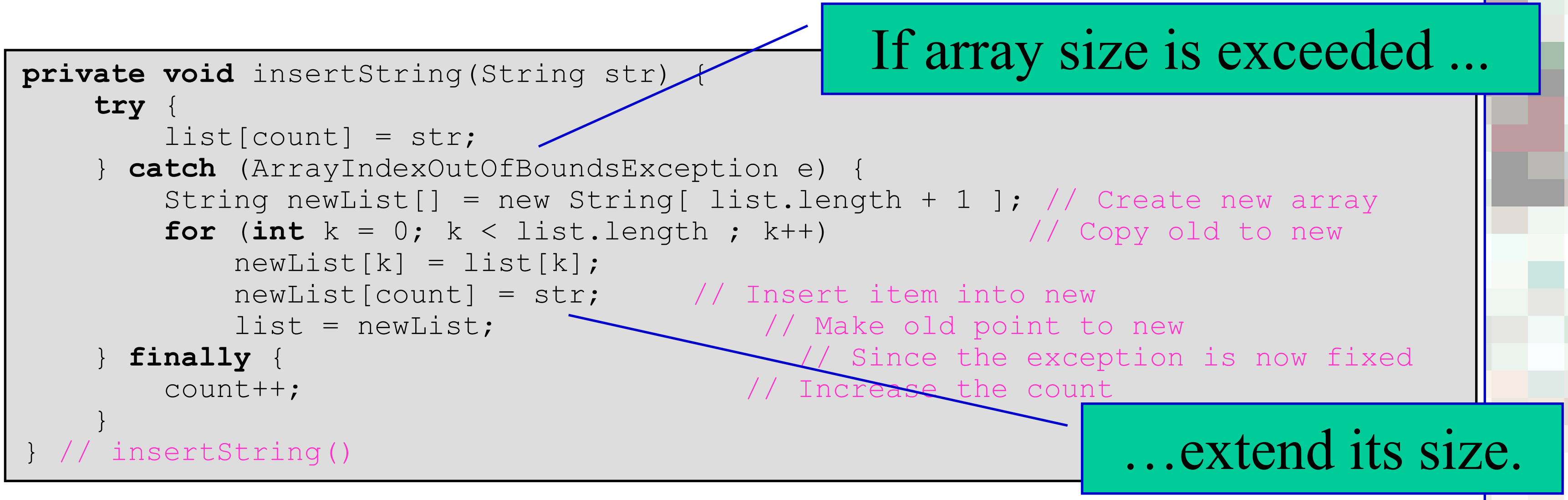
- Your own programs: letting Java handle exceptions may be the best choice.
- During program development: exceptions help you identify bugs.
- Commercial software: the program should handle its exceptions because the user can’t.

Handling Strategies

- **Print Error Message and Terminate.** Unless the error can be fixed, it’s better to terminate a program than to allow it to spread bad data -- e.g., the divide-by-zero example.
- **Log the Error and Resume**: A heart monitor program cannot be terminated.

When *Not* to Use an Exception

- **Effective Design:** Exceptions should ***not*** be used to handle routine conditions.
- If an array is routinely overflowed, use a Vector.



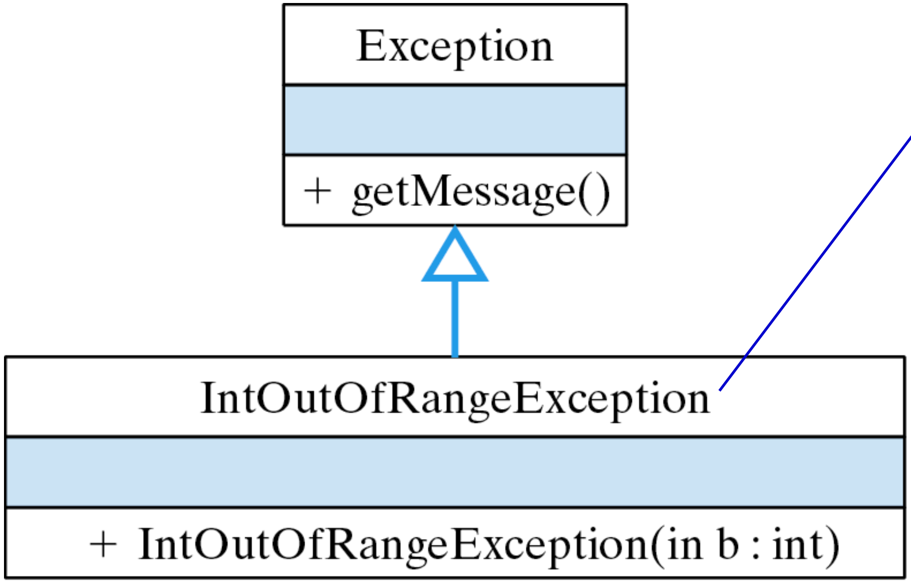
```
private void insertString(String str) {
    try {
        list[count] = str;
    } catch (ArrayIndexOutOfBoundsException e) {
        String newList[] = new String[ list.length + 1 ]; // Create new array
        for (int k = 0; k < list.length ; k++)           // Copy old to new
            newList[k] = list[k];
            newList[count] = str;     // Insert item into new
            list = newList;               // Make old point to new
    } finally {                             // Since the exception is now fixed
        count++;                         // Increase the count
    }
} // insertString()
```

If array size is exceeded ...

…extend its size.

Programmer-Defined Exceptions

- Programmer-defined exceptions are defined by extending the Exception class.



Thrown when an integer exceeds a certain bound.

Creating Your Own Exceptions

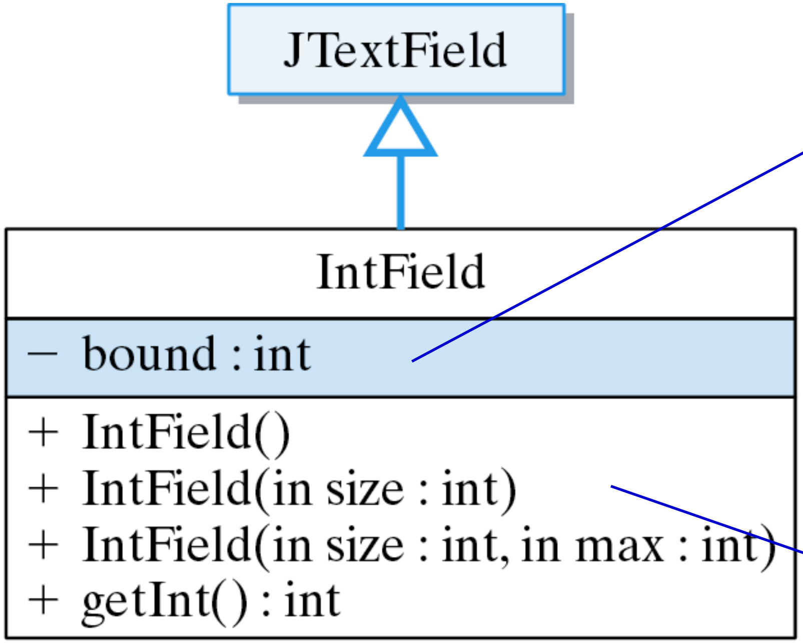
- An exception for validating that an integer is less than or equal to a certain maximum value:

```java
/**
 *  IntOutOfRangeException reports an exception when an
 *    integer exceeds its bound.
 */
public class IntOutOfRangeException extends Exception {

    public IntOutOfRangeException (int Bound) {
        super("The input value exceeds the bound " + Bound);
    }
}
```

This error message will be printed when this exception is thrown.

Example: Bounded Input

- Modified IntField that only accepts integers that are less than a certain bound.


JTextField
IntField
− bound : int
+ IntField()
+ IntField(in size : int)
+ IntField(in size : int, in max : int)
+ getInt() : int

An IntField with a bound.

Throws exception if bound exceeded.

Implementation: IntField

- Bound is set in the IntField constructor.

```
public class IntField extends JTextField {
        private int bound = Integer.MAX_VALUE;
        public IntField(int size, int max) {
            super(size);
            bound = max;
        }
        public int getInt() throws NumberFormatException,
                                       IntOutOfRangeException {
            int num = Integer.parseInt(getText());
            if (num > bound)
                throw new IntOutOfRangeException(bound);
            return num;
    } // getInt()
       // The rest of the class is unchanged
} // IntField
```

New constructor lets us set the bound.

Throw exception if bound exceeded.

Using Your Own Exception

- The IntFieldTester class tries to input an integer within a certain range:

```
public class IntFieldTester extends JPanel implements ActionListener  {
   // Code deleted here: unshown 'intField', 'userInt', and 'message'.
    public void actionPerformed(ActionEvent evt) {
        try {
            userInt = intField.getInt();
            message = "You input " + userInt + " Thank you.";
        } catch (NumberFormatException e) {
            JOptionPane.showMessageDialog(this,
               "The input must be an integer. Please reenter.");
        } catch (IntOutOfRangeException e) {
            JOptionPane.showMessageDialog(this, e.getMessage());
        } finally {
            repaint();
        }
    } // actionPerformed()
    // Code deleted here
} // IntFieldTester
```

Get user's input.

Handle exceptions.

An error dialog window.

Effective Design

- **Unfixable Error.** If possible, it’s better to terminate the program abnormally than to allow the error to propagate.
- **Normal versus Exceptional Code.** The exception handler --- the catch block --- is distinct from the (normal) code that throws the exception --- the try block.
- **Using an Exception.** If your exception handler is not significantly different from Java’s, let Java handle it.

Effective Design

- **Handling Exceptions.**
  - Report the exception and terminate the program;
  - Fix the exceptional condition and resume normal execution.
  - Report the exception to a log and resume execution.
- **Program Development.** Exceptions help identify design flaws during program development.
- **Report and Resume**. Failsafe programs should report the exception and resume.

Effective Design

- **Defensive Design.** Anticipate potential problems, especially potential input problems.
- **Fixing an Exception.** Handle fixable exceptions locally. This is both clearer and more efficient.
- **Library Exception Handling**. Many library classes leave exception handling to the application.
- **Truly Exceptional Conditions.** Use exceptions to handle truly exceptional conditions, not for expected conditions.

Technical Terms

- catch block
- catch an exception
- checked exception
- dialog box
- dynamic scope
- error dialog
- exception
- exception handler
- finally block
- method call stack
- method stack trace
- modal dialog
- static scope
- throw an exception
- try block
- unchecked exception

Summary Of Important Points

- In Java, when an error occurs, you throw an Exception which is caught by *exception handler* code . A *throw statement* --- throw new Exception() --- is used to throw an exception.
- A *try block* is contains one or more statements that may throw an exception. Embedding a statement in a try block indicates your awareness that it might throw an exception and your intention to handle the exception.

Summary Of Important Points (cont)

- *Checked exceptions* must be caught or declared by the method in which they occur.
- *Unchecked exceptions* (subclasses of RuntimeException) are handled by Java if they are not caught in the program.
- A *catch block* contains statements that handle the exception that matches its parameter.
- A catch block can only follow a try block.
- There may be more than one catch block for each try block.

Summary Of Important Points (cont)

- The try/catch syntax separates the normal parts of an algorithm from special exceptional handling code.
- A *method stack trace* is a trace of a program’s method calls -- Exception.printStackTrace().
- *Static scoping:* how the program is written. Depends on declarations and definitions.
- *Dynamic scoping:* how the program is executed. Depends on method calls.

Summary Of Important Points (cont)

- Finding a Catch Block: Search upward through the static scope, and backward through the dynamic scope.
- The Java Virtual Machine handles unchecked exceptions not caught by the program.
- Many Java library methods throw exceptions when an error occurs.
- Example: Java's integer division operator will throw an ArithmeticException if an attempt is made to divide by zero.

Summary Of Important Points (cont)

- Four ways to handle an exception:
  - Let Java handle it.
  - Fix the problem and resume the program.
  - Report the problem and resume the program.
  - Print an error message and terminate.
- The (optional) finally block contains code that will be executed whether an exception is raised or not.
- Exceptions should be used for exception truly exceptional conditions, not for normal program control.
- User-defined exceptions can extend the Exception class or one of its subclasses.