Exception Handling

CSE 114, Computer Science 1
SUNY Korea

Pradipta De
pradipta.de@sunykorea.ac.kr

Acknowledgement for the slides: Dr. Paul Fodor (CS Stony Brook)
Motivation

• When a program runs into a runtime error, the program terminates abnormally.

• We want to handle the runtime error so that the program can continue to run or terminate gracefully.
Exception in Java

• Runtime errors are caught by JVM
  • Program has compiled correctly, but error occurs while executing the program

• Examples:
  • Trying to access an array with an index which is out of bound
  • Input a double value when program expects integer type

• An exception is an object generated by Java runtime environment ➔ exception represents an error
  • If exception is not handled, program terminates
Exception-Handling

Runtime error: division with 0 (if the user enters 1 and 0)

```java
import java.util.Scanner;

public class Quotient {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        // Prompt the user to enter two integers
        System.out.print("Enter two integers: ");
        int number1 = input.nextInt();
        int number2 = input.nextInt();
        System.out.println(number1 + " / " + number2
                           + " is " +(number1 / number2));
    }
}
```

Enter two integers: 1 0
Exception in thread "main" java.lang.ArithmeticException: / by zero
at Quotient.main(Quotient.java:10)
Fix it using an if statement:

```java
import java.util.Scanner;

public class QuotientWithIf {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        // Prompt the user to enter two integers
        System.out.print("Enter two integers: ");
        int number1 = input.nextInt();
        int number2 = input.nextInt();
        if (number2 != 0)
            System.out.println(number1 + " / " + number2 + " is " +
                                (number1 / number2));
        else
            System.out.println("Divisor cannot be zero ");
    }
}
```
import java.util.Scanner;

public class QuotientWithException {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        // Prompt the user to enter two integers
        System.out.print("Enter two integers: ");
        int number1 = input.nextInt();
        int number2 = input.nextInt();
        try {
            System.out.println(number1 + " / " + number2 + " is "+ (number1 / number2));
        }catch (Exception ex) {
            System.out.println("Exception: an integer " +
                                "cannot be divided by zero ");
        }
        System.out.println("Execution continues ...");
    }
}
import java.util.Scanner;

public class QuotientWithMethod {
    public static int quotient(int number1, int number2) throws Exception {
        if (number2 == 0)
            throw new ArithmeticException("Divisor cannot be zero");
        return number1 / number2;
    }

    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        // Prompt the user to enter two integers
        System.out.print("Enter two integers: ");
        int number1 = input.nextInt();
        int number2 = input.nextInt();
        try {
            int result = quotient(number1, number2);
            System.out.println(number1 + " / " + number2 + " is " + result);
        } catch (Exception ex) {
            System.out.println("Exception: an integer " +
                    "cannot be divided by zero ");
        }
        System.out.println("Execution continues ...");
    }
}
Exception Advantages

- It enables **a method to throw an exception to its caller**.
- **Without this capability**, a method must handle the exception or terminate the program.
Template for try-throw-catch block

```java
try {
    Code to run;
    A statement or a method that may throw an exception;
    More code to run;
}
catch (type ex) {
    Code to process the exception;
}
```
Handling InputMismatchException

- By handling InputMismatchException, your program will continuously read an input until it is correct:

```java
import java.util.*;
public class InputMismatchExceptionDemo {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        boolean continueInput = true;
        do {
            try {
                System.out.print("Enter an integer: ");
                int number = input.nextInt();
                // Display the result
                System.out.println("The number entered is " + number);
                continueInput = false;
            } catch (InputMismatchException ex) {
                System.out.println("Try again. (" + "Incorrect input: " + 
                "an integer is required)");
                input.nextLine(); // discard input
            }
        } while (continueInput);
    }
}
```
Exception Types

Object → Throwable

Exception

ClassNotFoundException

IOException

RuntimeException

LinkageError

NullPointerException

IndexOutOfBoundsException

Many more classes

Error

VirtualMachineError

Many more classes

Many more classes

ArithmeticException

NullPointerException

IndexOutOfBoundsException

IllegalArgumentException

Many more classes
System errors are thrown by JVM and represented in the `Error` class. The `Error` class describes internal system errors. Such errors rarely occur. If one does, there is little you can do beyond notifying the user and trying to terminate the program gracefully.
Exception describes errors caused by your program and external circumstances. These errors can be caught and handled by your program.
RuntimeException is caused by programming errors, such as bad casting, accessing an out-of-bounds array, and numeric errors.
Checked Exceptions vs. Unchecked Exceptions

**Unchecked Exceptions**

`RuntimeException`, `Error` and their subclasses are known as *unchecked exceptions*.

All other exceptions are known as *checked exceptions*, meaning that the compiler forces the programmer to check and deal with the exceptions.

Java does NOT mandate that you write code to catch or declare unchecked exceptions.
Unchecked Exceptions

- Exception
  - ClassNotFoundException
  - VirtualMachineError
  - IOException
  - Exception
    - RuntimeException
      -LinkageError
      - Error
        - ArithmeticException
        - NullPointerException
        - IllegalArgumentException
        - Many more classes
  - Many more classes

Unchecked exceptions
Unchecked Exceptions

- In most cases, unchecked exceptions reflect programming logic errors that are not recoverable.
- For example, a `NullPointerException` is thrown if you access an object through a reference variable before an object is assigned to it;
- an `IndexOutOfBoundsException` is thrown if you access an element in an array outside the bounds of the array.
- These are the logic errors → correct in the program
- Unchecked exceptions can occur anywhere in the program.
- Java does not mandate you to write code to catch unchecked exceptions → code is cleaner
Declaring, Throwing, and Catching Exceptions

```java
method1() {
    try {
        invoke method2;
    }
    catch (Exception ex) {
        Process exception;
    }
}

method2() throws Exception {
    if (an error occurs) {
        throw new Exception();
    }
}
```

- catch exception
- throw exception
- declare exception
Declaring Exceptions

- Every method must state the types of checked exceptions it might throw. This is known as *declaring exceptions*:

  ```java
  public void myMethod() throws IOException
  public void myMethod() throws IOException, OtherException, ...
  ```
Throwing Exceptions

• When the program detects an error, the program can create an instance of an appropriate exception type and throw it - known as *throwing an exception*:

```java
throw new TheException();
```

OR

```java
TheException ex = new TheException();
throw ex;
```
/** Set a new radius */
    public void setRadius(double newRadius) throws IllegalArgumentException {
        if (newRadius >= 0)
            radius = newRadius;
        else
            throw new IllegalArgumentException("Radius cannot be negative");
    }
try {
    // Statements that may throw exceptions
    ...
    }catch (ExceptionType1 exVar1) {
        handler for exception1;
    }catch (ExceptionType2 exVar2) {
        handler for exception2;
    }
    ...
    }catch (ExceptionTypeN exVarN) {
        handler for exceptionN;
    }
Catching Exceptions

main method {
  ...
  try {
    ...
    invoke method1;
    statement1;
  } catch (Exception1 ex1) {
    Process ex1;
  } statement2;
}

method1 {
  ...
  try {
    ...
    invoke method2;
    statement3;
  } catch (Exception2 ex2) {
    Process ex2;
  } statement4;
}

method2 {
  ...
  try {
    ...
    invoke method3;
    statement5;
  } catch (Exception3 ex3) {
    Process ex3;
  } statement6;
}

An exception is thrown in method3
### Catch or Declare Checked Exceptions

- Java forces you to deal with **checked exceptions**:
  - If a method declares a checked exception (i.e., an exception other than `Error` or `RuntimeException`), you must invoke it in a `try-catch` block or declare to throw the exception in the calling method.
  - For example, suppose that method `p1` invokes method `p2` and `p2` may throw a checked exception (e.g., `IOException`), you have to write the code: (a) or (b):

```java
void p1() {
    try {
        p2();
    }
    catch (IOException ex) {
        ...
    }
}
```

(a)

```java
void p1() throws IOException {
    p2();
}
```

(b)
public class CircleWithException {
    private double radius; /** The radius of the circle */
    private static int numberOfObjects = 0; /** The number of the objects created */
    public CircleWithException() {this(1.0); } /* Construct a circle with radius 1 */
    public CircleWithException(double newRadius) throws IllegalArgumentException {
        setRadius(newRadius);
        numberOfObjects++;
    }
    public double getRadius() { return radius; }
    public void setRadius(double newRadius) throws IllegalArgumentException {
        if (newRadius >= 0)
            radius = newRadius;
        else
            throw new IllegalArgumentException("Radius cannot be negative");
    }
    public static int getNumberOfObjects() {/** Return numberOfObjects */
        return numberOfObjects;
    }
    public double findArea() {/** Return the area of this circle */
        return radius * radius * 3.14159;
    }
}
public static void main(String[] args) {
    try {
        CircleWithException c1 = new CircleWithException(5);
        CircleWithException c2 = new CircleWithException(-5);
        CircleWithException c3 = new CircleWithException(0);
    } catch (IllegalArgumentException ex) {
        System.out.println(ex);
    }
    System.out.println("Number of objects created: " +
        CircleWithException.getNumberOfObjects());
}
Rethrowing Exceptions

```java
try {
    statements;
} catch(TheException ex) {
    throw ex;
}
```
Order of catch blocks

- Order in which exceptions are specified in catch blocks is important
- Compile error if catch block for a superclass precedes catch block for a subclass

(a) Wrong order
(b) Correct order
try {
    statements;
} catch(TheException ex) {
    handling ex;
} finally {
    finalStatements;
}

The finally block *always* executes when the try block exits
Useful for cleanup code:

...  
}finally {
    if (out != null) {
        System.out.println("Closing PrintWriter");
        out.close();
    }
}

The catch block can be omitted when the finally clause is used
When Using Exceptions

- Exception handling separates error-handling code from normal programming tasks, thus making programs easier to read and to modify.

- Exception handling usually requires more time and resources because it requires instantiating a new exception object, rolling back the call stack, and propagating the errors to the calling methods.
When to Throw Exceptions

• An exception occurs in a method:
  • If you want the exception to be processed by its caller, you should create an exception object and throw it.
  • If you can handle the exception in the method where it occurs, there is no need to throw it.
When to Use Exceptions

- You should only use exceptions to deal with unexpected error conditions.
  - Do not use it to deal with simple, expected situations:
    ```java
    try {
      System.out.println(refVar.toString());
    } catch (NullPointerException ex) {
      System.out.println("refVar is null");
    }
    ```

    is better to be replaced by
    ```java
    if (refVar != null)
      System.out.println(refVar.toString());
    else
      System.out.println("refVar is null");
    ```
Defining Custom Exception Classes

- Use the exception classes in the API whenever possible.
- Define custom exception classes if the predefined classes are not sufficient.
- Define custom exception classes by extending Exception or a subclass of Exception.
public class InvalidRadiusException extends Exception {
    private double radius;

    /** Construct an exception */
    public InvalidRadiusException(double radius) {
        super("Invalid radius " + radius);
        this.radius = radius;
    }

    /** Return the radius */
    public double getRadius() {
        return radius;
    }
}

public class CircleWithRadiusException {
    private double radius;
    public CircleWithRadiusException(double newRadius) {
        try {
            setRadius(newRadius);
            numberOfObjects++;
        }
        catch (InvalidRadiusException ex) {
            ex.printStackTrace();
        }
    }
    public void setRadius(double newRadius) throws InvalidRadiusException {
        if (newRadius >= 0)
            radius = newRadius;
        else
            throw new InvalidRadiusException(newRadius);
    }
    public static void main(String[] args) {
        CircleWithRadiusException cwe = new CircleWithRadiusException(5.0);
    }
}

Custom Exception Class Example
Text I/O: The **File** Class

- The **File** class is intended to provide an abstraction that deals with most of the machine-dependent complexities of files and path names in a machine-independent fashion.
  - The filename is a string
  - The **File** class is a wrapper class for the file name and its directory path
<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+File(pathname: String)</td>
<td>Creates a File object for the specified pathname. The pathname may be a directory or a file.</td>
</tr>
<tr>
<td>+File(parent: String, child: String)</td>
<td>Creates a File object for the child under the directory parent. child may be a filename or a subdirectory.</td>
</tr>
<tr>
<td>+File(parent: File, child: String)</td>
<td>Creates a File object for the child under the directory parent. parent is a File object. In the preceding constructor, the parent is a string.</td>
</tr>
<tr>
<td>+exists(): boolean</td>
<td>Returns true if the file or the directory represented by the File object exists.</td>
</tr>
<tr>
<td>+canRead(): boolean</td>
<td>Returns true if the file represented by the File object exists and can be read.</td>
</tr>
<tr>
<td>+canWrite(): boolean</td>
<td>Returns true if the file represented by the File object exists and can be written.</td>
</tr>
<tr>
<td>+isDirectory(): boolean</td>
<td>Returns true if the File object represents a directory.</td>
</tr>
<tr>
<td>+isFile(): boolean</td>
<td>Returns true if the File object represents a file.</td>
</tr>
<tr>
<td>+isAbsolute(): boolean</td>
<td>Returns true if the File object is created using an absolute path name.</td>
</tr>
<tr>
<td>+isHidden(): boolean</td>
<td>Returns true if the file represented in the File object is hidden. The exact definition of hidden is system-dependent. On Windows, you can mark a file hidden in the File Properties dialog box. On Unix systems, a file is hidden if its name begins with a period character &quot;.&quot;.</td>
</tr>
<tr>
<td>+getAbsolutePath(): String</td>
<td>Returns the complete absolute file or directory name represented by the File object.</td>
</tr>
<tr>
<td>+getCanonicalPath(): String</td>
<td>Returns the same as getAbsolutePath() except that it removes redundant names, such as &quot;.&quot; and &quot;..&quot;, from the pathname, resolves symbolic links (on Unix platforms), and converts drive letters to standard uppercase (on Win32 platforms).</td>
</tr>
<tr>
<td>+getName(): String</td>
<td>Returns the last name of the complete directory and file name represented by the File object. For example, new File(&quot;c:\book\test.dat&quot;).getName() returns test.dat.</td>
</tr>
<tr>
<td>+getPath(): String</td>
<td>Returns the complete directory and file name represented by the File object. For example, new File(&quot;c:\book\test.dat&quot;).getPath() returns c:\book\test.dat.</td>
</tr>
<tr>
<td>+getParent(): String</td>
<td>Returns the complete parent directory of the current directory or the file represented by the File object. For example, new File(&quot;c:\book\test.dat&quot;).getParent() returns c:\book.</td>
</tr>
<tr>
<td>+lastModified(): long</td>
<td>Returns the time that the file was last modified.</td>
</tr>
<tr>
<td>+delete(): boolean</td>
<td>Deletes this file. The method returns true if the deletion succeeds.</td>
</tr>
<tr>
<td>+renameTo(dest: File): boolean</td>
<td>Renames this file. The method returns true if the operation succeeds.</td>
</tr>
</tbody>
</table>
Text I/O

- A **File** object encapsulates the properties of a file or a path, but *does not contain the methods for reading/writing data* from/to a file.

- In order to perform I/O, you need to create objects using appropriate Java I/O classes: **Scanner** and **PrintWriter**
Writing Data Using PrintWriter

<table>
<thead>
<tr>
<th>java.io.PrintWriter</th>
</tr>
</thead>
<tbody>
<tr>
<td>+PrintWriter(filename: String)</td>
</tr>
<tr>
<td>+print(s: String): void</td>
</tr>
<tr>
<td>+print(c: char): void</td>
</tr>
<tr>
<td>+print(cArray: char[]): void</td>
</tr>
<tr>
<td>+print(i: int): void</td>
</tr>
<tr>
<td>+print(l: long): void</td>
</tr>
<tr>
<td>+print(f: float): void</td>
</tr>
<tr>
<td>+print(d: double): void</td>
</tr>
<tr>
<td>+print(b: boolean): void</td>
</tr>
</tbody>
</table>

Also contains the overloaded println methods.

Also contains the overloaded printf methods.

Creates a PrintWriter for the specified file.

Writes a string.

Writes a character.

Writes an array of character.

Writes an int value.

Writes a long value.

Writes a float value.

Writes a double value.

Writes a boolean value.

A println method acts like a print method; additionally it prints a line separator. The line separator string is defined by the system. It is \r\n on Windows and \n on Unix.

The printf method was introduced in §3.6, “Formatting Console Output and Strings.”
public class WriteData {
    public static void main(String[] args)
        throws Exception {
            java.io.File file = new java.io.File("scores.txt");
            if (file.exists()) {
                System.out.println("File already exists");
                System.exit(0);
            }
            // Create the file
            java.io.PrintWriter output = new java.io.PrintWriter(file);
            // Write output to the file
            output.print("John T Smith ");
            // Close the file
            output.close();
        }
}
Reading Data Using Scanner

java.util.Scanner

+Scanner(source: File) Creates a Scanner that produces values scanned from the specified file.
+Scanner(source: String) Creates a Scanner that produces values scanned from the specified string.
+close() Closes this scanner.
+hasNext(): boolean Returns true if this scanner has another token in its input.
+next(): String Returns next token as a string.
+nextByte(): byte Returns next token as a byte.
+nextShort(): short Returns next token as a short.
+nextInt(): int Returns next token as an int.
+nextLong(): long Returns next token as a long.
+nextFloat(): float Returns next token as a float.
+nextDouble(): double Returns next token as a double.
+useDelimiter(pattern: String): Scanner Sets this scanner’s delimiting pattern.
import java.util.Scanner;
public class ReadData {
    public static void main(String[] args) throws Exception {
        // Create a File instance
        java.io.File file = new java.io.File("scores.txt");
        // Create a Scanner for the file
        Scanner input = new Scanner(file);
        // Read data from a file
        while (input.hasNext()) {
            String firstName = input.next();
            int score = input.nextInt();
            System.out.println(Name + " " + score);
        }
        // Close the file
        input.close();
    }
}