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Lecture 10: Exception Handling

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Exception Handling

- An *exception* is an abnormal condition that arises in a code sequence at run time.
- In other words, an exception is a runtime error.
- In computer languages that do not support exception handling, errors must be checked and handled manually—typically through the use of error codes, and so on.
- This approach is as cumbersome as it is troublesome.
- Java's exception handling avoids these problems and, in the process, brings run-time error management into the object-oriented world.
- Exceptions can be generated by the Java run-time system, or they can be manually generated by your code.

Java Exception Handling

- Java exception handling is managed via five keywords:
  - **try**, **catch**, **throw**, **throws**, and **finally**.
- Program statements that you want to monitor for exceptions are contained within a **try** block.
- If an exception occurs within the **try** block, it is thrown.
- Your code can catch this exception (using **catch**) and handle it in some rational manner.
- System-generated exceptions are automatically thrown by the Java runtime system.
- To manually throw an exception, use the keyword **throw**.
- Any exception that is thrown out of a method must be specified as such by a **throws** clause.
- Any code that absolutely must be executed after a **try** block completes is put in a **finally** block.

General form of an exception-handling block

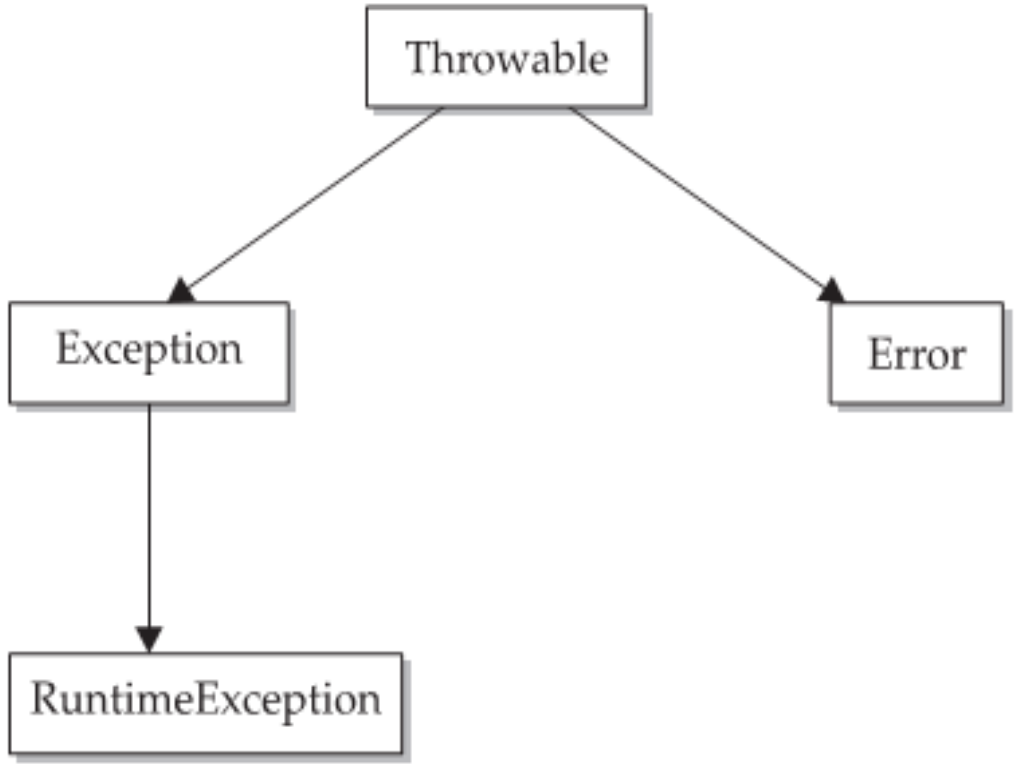
```
try {
    // block of code to monitor for errors
}

catch (ExceptionType1 exOb) {
    // exception handler for ExceptionType1
}

catch (ExceptionType2 exOb) {
    // exception handler for ExceptionType2
}
// ...
finally {
    // block of code to be executed after try block ends
}
```

Exception Types

- All exception types are subclasses of the built-in class **Throwable**.
- **Exception**class is used for exceptional conditions that user programs should catch.
  - This is also the class that you will subclass to create your own custom exception types.
- **RuntimeException** of this type are automatically defined for the programs that you write and include things such as division by zero and invalid array indexing.
- Exceptions of type **Error** are used by the Java run-time system to indicate errors having to do with the run-time environment, itself.
  - Stack overflow is an example of such an error.



Uncaught Exceptions

Example #1

```
class Exc0 {
  public static void main(String args[]) {
    int d = 0;
    int a = 42 / d;
  }
}
```

```
java.lang.ArithmeticException: / by zero
        at Exc0.main(Exc0.java:4)
```

- What happens when you don’t handle them?
- Any exception that is not caught by your program will ultimately be processed by the default handler provided by the Java run-time system.
- The default handler displays a string describing the exception, prints a stack trace from the point at which the exception occurred, and terminates the program
- Notice how the class name, **Exc0**; the method name, **main**; the filename, **Exc0.java**; and the line number, **4**, are all included in the simple stack trace.

Uncaught Exceptions

```
class Exc1 {
  static void subroutine() {
    int d = 0;
    int a = 10 / d;
  }
  public static void main(String args[]) {
    Exc1.subroutine();
  }
}
```

Example #2

```
java.lang.ArithmeticException: / by zero
    at Exc1.subroutine(Exc1.java:4)
    at Exc1.main(Exc1.java:7)
```

Using try and catch

- Although the default exception handler provided by the Java run-time system is useful for debugging, you will usually want to handle an exception yourself.
- Doing so provides two benefits.
  - First, it allows you to fix the error.
  - Second, it prevents the program from automatically terminating.
- To guard against and handle a run-time error, simply enclose the code that you want to monitor inside a **try** block.
- Immediately following the **try** block, include a **catch** clause that specifies the exception type that you wish to catch.

Example #3

```
class Exc2 {
  public static void main(String args[]) {
    int d, a;

    try { // monitor a block of code.
     d = 0;
     a = 42 / d;
     System.out.println("This will not be printed.");
    } catch (ArithmeticException e) { // catch divide-by-zero error
     System.out.println("Division by zero.");
    }


    System.out.println("After catch statement.");
  }
}
```

This program generates the following output:

```
Division by zero.
After catch statement.
```

Using try and catch

- Notice that the call to **println( )** inside the **try** block is never executed.
- Once an exception is thrown, program control transfers out of the **try** block into the **catch** block.
- Put differently, **catch** is not “called,” so execution never “returns” to the **try** block from a **catch**.
- Thus, the line "This will not be printed." is not displayed.
- A **try** and its **catch** statement form a unit.
- The scope of the **catch** clause is restricted to those statements specified by the immediately preceding **try** statement.
- A **catch** statement cannot catch an exception thrown by another **try** statement (except in the case of nested **try** statements)
- The statements that are protected by **try** must be surrounded by curly braces.
  - (That is, they must be within a block.) You cannot use **try** on a single statement.

Example #4

```
// Handle an exception and move on.
import java.util.Random;

class HandleError {
  public static void main(String args[]) {
    int a=0, b=0, c=0;
    Random r = new Random();

    for(int i=0; i<32000; i++) {
      try {
        b = r.nextInt();
        c = r.nextInt();
        a = 12345 / (b/c);
      } catch (ArithmeticException e) {
        System.out.println("Division by zero.");
        a = 0; // set a to zero and continue
      }
      System.out.println("a: " + a);
    }
  }
}
```

Multiple catch Clauses

- In some cases, more than one exception could be raised by a single piece of code.
- To handle this type of situation, you can specify two or more **catch** clauses, each catching a different type of exception.
- When an exception is thrown, each **catch** statement is inspected in order, and the first one whose type matches that of the exception is executed.
- After one **catch** statement executes, the others are bypassed, and execution continues after the **try / catch** block.

Example #5

```
// Demonstrate multiple catch statements.
class MultipleCatches {
  public static void main(String args[]) {
    try {
       int a = args.length;
      System.out.println("a = " + a);
      int b = 42 / a;
      int c[] = { 1 };
      c[42] = 99;
    } catch(ArithmeticException e) {
      System.out.println("Divide by 0: " + e);
    } catch(ArrayIndexOutOfBoundsException e) {
      System.out.println("Array index oob: " + e);
    }
    System.out.println("After try/catch blocks.");
  }
}
```

```
C:\>java MultipleCatches
a = 0
Divide by 0: java.lang.ArithmeticException: / by zero
After try/catch blocks.

C:\>java MultipleCatches TestArg
a = 1
Array index oob:  java.lang.ArrayIndexOutOfBoundsException:42
After try/catch blocks.
```

Multiple catch Clauses

- When you use multiple **catch** statements, it is important to remember that exception subclasses must come before any of their superclasses.
- This is because a **catch** statement that uses a superclass will catch exceptions of that type plus any of its subclasses.
- Thus, a subclass would never be reached if it came after its superclass.

Example #6

```
/* This program contains an error.

   A subclass must come before its superclass in
   a series of catch statements. If not,
   unreachable code will be created and a
   compile-time error will result.
*/
class SuperSubCatch {
  public static void main(String args[]) {
    try {
      int a = 0;
      int b = 42 / a;
     } catch(Exception e) {
       System.out.println("Generic Exception catch.");
    }
    /* This catch is never reached because
       ArithmeticException is a subclass of Exception. */
    catch(ArithmeticException e) { // ERROR - unreachable
      System.out.println("This is never reached.");
    }
  }
}
```

To fix the problem, reverse the order of the Catch statements.

Nested try Statements

- The **try** statement can be nested.
- That is, a **try** statement can be inside the block of another **try**.
- Each time a **try** statement is entered, the context of that exception is pushed on the stack.
- If an inner **try** statement does not have a **catch** handler for a particular exception,
  the stack is unwound and the next **try** statement's **catch** handlers are inspected for a match.
- This continues until one of the **catch** statements succeeds, or until all of the nested **try** statements are exhausted.
- If no **catch** statement matches, then the Java run-time system will handle the exception.

Example #7

```
// An example of nested try statements.
class NestTry {
  public static void main(String args[]) {
    try {
      int a = args.length;

      /* If no command-line args are present,
          the following statement will generate
          a divide-by-zero exception. */
      int b = 42 / a;

       System.out.println("a = " + a);

       try { // nested try block
         /* If one command-line arg is used,
            then a divide-by-zero exception
            will be generated by the following code. */
        if(a==1) a = a/(a-a); // division by zero

        /* If two command-line args are used,
           then generate an out-of-bounds exception. */
        if(a==2) {
           int c[] = { 1 };
           c[42] = 99; // generate an out-of-bounds exception
        }
      } catch(ArrayIndexOutOfBoundsException e) {
        System.out.println("Array index out-of-bounds: " + e);
      }

    } catch(ArithmeticException e) {
      System.out.println("Divide by 0: " + e);
    }
  }
```

```
C:\>java NestTry
Divide by 0: java.lang.ArithmeticException: / by zero

C:\>java NestTry One
a = 1
Divide by 0: java.lang.ArithmeticException: / by zero

C:\>java NestTry One Two
a = 2
Array index out-of-bounds:
  java.lang.ArrayIndexOutOfBoundsException:42
```

throw

- So far, you have only been catching exceptions that are thrown by the Java run-time system.
- However, it is possible for your program to throw an exception explicitly, using the **throw** statement.
- The general form of **throw** is shown here:

  throw *ThrowableInstance;*
- Here, *ThrowableInstance* must be an object of type **Throwable** or a subclass of **Throwable**.
- Primitive types, such as **int** or **char**, as well as non-**Throwable** classes, such as **String** and **Object**, cannot be used as exceptions.
- There are two ways you can obtain a **Throwable** object: using a parameter in a **catch** clause or creating one with the **new** operator.

```
// Demonstrate throw.
class ThrowDemo {
  static void demoproc() {
    try {
      throw new NullPointerException("demo");
    } catch(NullPointerException e) {
      System.out.println("Caught inside demoproc.");
      throw e; // rethrow the exception
    }
  }

  public static void main(String args[]) {
    try {
      demoproc();
    } catch(NullPointerException e) {
      System.out.println("Recaught: " + e);
    }
  }
}
```

Example #8

Here is the resulting output:

```
Caught inside demoproc.
Recaught: java.lang.NullPointerException: demo
```

throws

- If a method is capable of causing an exception that it does not handle, it must specify this behavior so that callers of the method can guard themselves against that exception.
- You do this by including a **throws** clause in the method's declaration.
- A **throws** clause lists the types of exceptions that a method might throw.
- This is necessary for all exceptions, except those of type **Error** or **RuntimeException**, or any of their subclasses.
- All other exceptions that a method can throw must be declared in the **throws** clause.
- If they are not, a compile-time error will result.
- This is the general form of a method declaration that includes a **throws** clause:
  type method-name(*parameter-list*) throws *exception-list*
  {
  // body of method
  }

```
// This program contains an error and will not compile.
class ThrowsDemo {
  static void throwOne() {
    System.out.println("Inside throwOne.");
    throw new IllegalAccessException("demo");
  }
  public static void main(String args[]) {
    throwOne();
  }
}
```

Example #9

- To make this example compile, you need to make two changes.
- First, you need to declare that **throwOne( )** throws **IllegalAccessException**.
- Second, **main( )** must define a **try / catch** statement that catches this exception.

```
// This is now correct.
class ThrowsDemo {
  static void throwOne() throws IllegalAccessException {
    System.out.println("Inside throwOne.");
    throw new IllegalAccessException("demo");
  }
  public static void main(String args[]) {
    try {
      throwOne();
    } catch (IllegalAccessException e) {
      System.out.println("Caught " + e);
    }
  }
}
```

Example #9

Here is the output generated by running this example program:

```
inside throwOne
caught java.lang.IllegalAccessException: demo
```

finally

- When exceptions are thrown, execution in a method takes a rather abrupt, nonlinear path that alters the normal flow through the method.
- Depending upon how the method is coded, it is even possible for an exception to cause the method to return prematurely.
- This could be a problem in some methods.
- For example, if a method opens a file upon entry and closes it upon exit, then you will not want the code that closes the file to be bypassed by the exception-handling mechanism.
- The **finally** keyword is designed to address this contingency.

finally

- **finally** creates a block of code that will be executed after a **try /catch** block has completed and before the code following the **try/catch** block.
- The **finally** block will execute whether or not an exception is thrown.
- If an exception is thrown, the **finally** block will execute even if no **catch** statement matches the exception.
- The **finally** clause is optional.
- However, each **try** statement requires at least one **catch** or a **finally** clause.

Example #10

```
// Demonstrate finally.
class FinallyDemo {
  // Throw an exception out of the method.
  static void procA() {
    try {
      System.out.println("inside procA");
      throw new RuntimeException("demo");
    } finally {
      System.out.println("procA's finally");
    }
  }

  // Return from within a try block.
  static void procB() {
    try {
      System.out.println("inside procB");
      return;
    } finally {
      System.out.println("procB's finally");
    }
  }

  // Execute a try block normally.
  static void procC() {
    try {
      System.out.println("inside procC");
    } finally {
      System.out.println("procC's finally");
    }
  }

  public static void main(String args[]) {
    try {
      procA();
    } catch (Exception e) {
      System.out.println("Exception caught");
    }

    procB();
    procC();
  }
}
```

output

```
inside procA
procA's finally
Exception caught
inside procB
procB's finally
inside procC
procC's finally
```

Exception	Meaning
ArithmeticException	Arithmetic error, such as divide-by-zero.
ArrayIndexOutOfBoundsException	Array index is out-of-bounds.
ArrayStoreException	Assignment to an array element of an incompatible type.
ClassCastException	Invalid cast.
EnumConstantNotPresentException	An attempt is made to use an undefined enumeration value.
IllegalArgumentException	Illegal argument used to invoke a method.
IllegalMonitorStateException	Illegal monitor operation, such as waiting on an unlocked thread.
IllegalStateException	Environment or application is in incorrect state.
IllegalThreadStateException	Requested operation not compatible with current thread state.
IndexOutOfBoundsException	Some type of index is out-of-bounds.
NegativeArraySizeException	Array created with a negative size.
NullPointerException	Invalid use of a null reference.
NumberFormatException	Invalid conversion of a string to a numeric format.
SecurityException	Attempt to violate security.
StringIndexOutOfBounds	Attempt to index outside the bounds of a string.
TypeNotPresentException	Type not found.
UnsupportedOperationException	An unsupported operation was encountered.

Java's Built-in Exceptions

RuntimeException

Defined in **java.lang**

Java's Built-in Exceptions

Exception	Meaning
ClassNotFoundException	Class not found.
CloneNotSupportedException	Attempt to clone an object that does not implement the **Cloneable** interface.
IllegalAccessException	Access to a class is denied.
InstantiationException	Attempt to create an object of an abstract class or interface.
InterruptedException	One thread has been interrupted by another thread.
NoSuchFieldException	A requested field does not exist.
NoSuchMethodException	A requested method does not exist.
ReflectiveOperationException	Superclass of reflection-related exceptions.

Creating Your Own Exception Subclasses

- Although Java's built-in exceptions handle most common errors, you will probably want to create your own exception types to handle situations specific to your applications.
- This is quite easy to do: just define a subclass of **Exception** (which is, of course, a subclass of **Throwable**).
- Your subclasses don't need to actually implement anything—it is their existence in the type system that allows you to use them as exceptions.

Method	Description
final void addSuppressed(Throwable *exc*)	Adds *exc* to the list of suppressed exceptions associated with the invoking exception. Primarily for use by the **try**-with-resources statement.
Throwable fillInStackTrace( )	Returns a **Throwable** object that contains a completed stack trace. This object can be rethrown.
Throwable getCause( )	Returns the exception that underlies the current exception. If there is no underlying exception, **null** is returned.
String getLocalizedMessage( )	Returns a localized description of the exception.
String getMessage( )	Returns a description of the exception.
StackTraceElement[ ] getStackTrace( )	Returns an array that contains the stack trace, one element at a time, as an array of **StackTraceElement**. The method at the top of the stack is the last method called before the exception was thrown. This method is found in the first element of the array. The **StackTraceElement** class gives your program access to information about each element in the trace, such as its method name.

Method	Description
final Throwable[ ] getSuppressed( )	Obtains the suppressed exceptions associated with the invoking exception and returns an array that contains the result. Suppressed exceptions are primarily generated by the **try**-with-resources statement.
Throwable initCause(Throwable *causeExc*)	Associates *causeExc* with the invoking exception as a cause of the invoking exception. Returns a reference to the exception.
void printStackTrace( )	Displays the stack trace.
void printStackTrace(PrintStream *stream*)	Sends the stack trace to the specified stream.
void printStackTrace(PrintWriter *stream*)	Sends the stack trace to the specified stream.
void setStackTrace(StackTraceElement *elements*[ ])	Sets the stack trace to the elements passed in *elements*. This method is for specialized applications, not normal use.
String toString( )	Returns a **String** object containing a description of the exception. This method is called by **println( )** when outputting a **Throwable** object.

Example #11

```
// This program creates a custom exception type.
class MyException extends Exception {
  private int detail;

  MyException(int a) {
    detail = a;
  }

  public String toString() {
    return "MyException[" + detail + "]";
  }
}
```

```
class ExceptionDemo {
  static void compute(int a) throws MyException {
    System.out.println("Called compute(" + a + ")");
    if(a > 10)
      throw new MyException(a);
    System.out.println("Normal exit");
  }

  public static void main(String args[]) {
    try {
      compute(1);
      compute(20);
    } catch (MyException e) {
      System.out.println("Caught " + e);
    }
  }
}
```

```
Called compute(1)
Normal exit
Called compute(20)
Caught MyException[20]
```