Exception Handling

An exception is an abnormal event that arises during the execution of the program and disrupts the normal flow of the program. Abnormality do occur when your program is running. For example, you might expect the user to enter an integer, but receive a text string; or an unexpected I/O error pops up at runtime.

What really matters is "what happens after an abnormality occurred?" In other words, "how the abnormal situations are handled by your program." If these exceptions are not handled properly, the program terminates abruptly and may cause severe consequences. For example, the network connections, database connections and files may remain opened; database and file records may be left in an inconsistent state.

The programmer faces two types of problems in coding – problems arising at **Compile-time** and problems arising at **Runtime**

1. Compile Time Errors

- All syntax errors detected and displayed by java compiler are known as Compile Time Errors. Whenever the compiler displays an error, it will not create the .class file. It is therefore necessary to fix all the errors before compile and run the program.
- Compile time errors occur due to typing mistakes
- Examples
  - Missing semicolons
  - Use of undeclared variables
  - Incompatible types in assignments
  - Misspelling of identifiers and keywords

2. Run Time Errors

- Sometimes, a program may compile successfully creating the .class file but may not run properly. Such programs may produce wrong results due to wrong logic, wrong input and may terminate.
- Most common Runtime Errors are :
  - Dividing an integer by zero
  - Accessing an element that is out of the bounds of an array
  - Trying to store incompatible value
  - Etc.

Program N0.

Exception Demo

```
import java.util.*;


public class ExceptionDemo_130
{
	public static void main(String[] args)
	{
		Scanner scan = new Scanner(System.in);
		int age;


		System.out.print("\n\t Enter age :");
		age = scan.nextInt();
```

```
            System.out.println("\n\t Age = " + age);
            System.out.println("\n\t End of Program");
      }
}
```

Java has a built-in mechanism for handling runtime errors, referred to as exception handling. This is to ensure that you can write robust programs for mission-critical applications.

Older programming languages such as C have some drawbacks in exception handing. For example, suppose the programmer wishes to open a file for processing:

1. The programmers are not made to aware of the exceptional conditions. For example, the file to be opened may not necessarily exist. The programmer therefore did not write codes to test whether the file exists before opening the file.
2. Suppose the programmer is aware of the exceptional conditions, he/she might decide to finish the main logic first, and write the exception handling codes later – this "later", unfortunately, usually never happens. In other words, you are not force to write the exception handling codes together with the main logic.
3. Suppose the programmer decided to write the exception handling codes, the exception handling codes *intertwine* with the main logic in many if-else statements. This makes main logic hard to follow and the entire program hard to read. For example,

```
if (file exists) {
   open file;
   while (there is more records to be processed) {
      if (no IO errors) {
         process the file record
      } else {
         handle the errors
      }
   }
   if (file is opened) close the file;
} else {
   report the file does not exist;
}
```

Java overcomes these drawbacks by building the exception handling into the language rather than leaving it to the discretion of the programmers:

1. You will be informed of the exceptional conditions that may arise in calling a method - Exceptions are declared in the method's signature.
2. You are forced to handle exceptions while writing the main logic and cannot leave them as an afterthought - Your program cannot compiled without the exception handling codes.
3. Exception handling codes are separated from the main logic - Via the `try-catch-finally` construct.

Exception

- An exception is a problem that arises during the execution of a program. An exception can occur for many different reasons, including the following:
    - A user has entered invalid data.
    - A file that needs to be opened cannot be found.
    - A network connection has been lost in the middle of communications or the JVM has run out of memory.
- Some of these exceptions are caused by user error, others by programmer error, and others by physical resources that have failed in some manner.

How Exception Handling

The purpose of exception handling mechanism is to provide a system to detect and report an “Exceptional circumstance” so that appropriate actions can be taken.

- Exception handling mechanism have following tasks
  1. Find the Problem **(Hit the Exception)**
  2. Inform that an error has occurred **(Throw the Exception)**
  3. Receive the Error information **(Catch the Exception)**
  4. Take corrective actions **(Handle the Exception)**

How to Handle Exception

Java uses try block that contains one or more statements that could generate an exception.

Syntax

```
try
{
      //statements that cause Exception
}
catch(ExceptionType obj)
{
      //statements that handle Exception
}
```

- If any statement generates an Exception, the remaining statements in the block are skipped and execution jumps to the catch block.
- The catch block “catches” the exception “thrown” by the try block and handles it appropriately.
- The catch statement is passed a single parameter, which is reference to the Exception object thrown.
- If the catch parameter matches with the type of exception object, then the exception is caught and statements in the catch block will be executed.

Program NO. 131

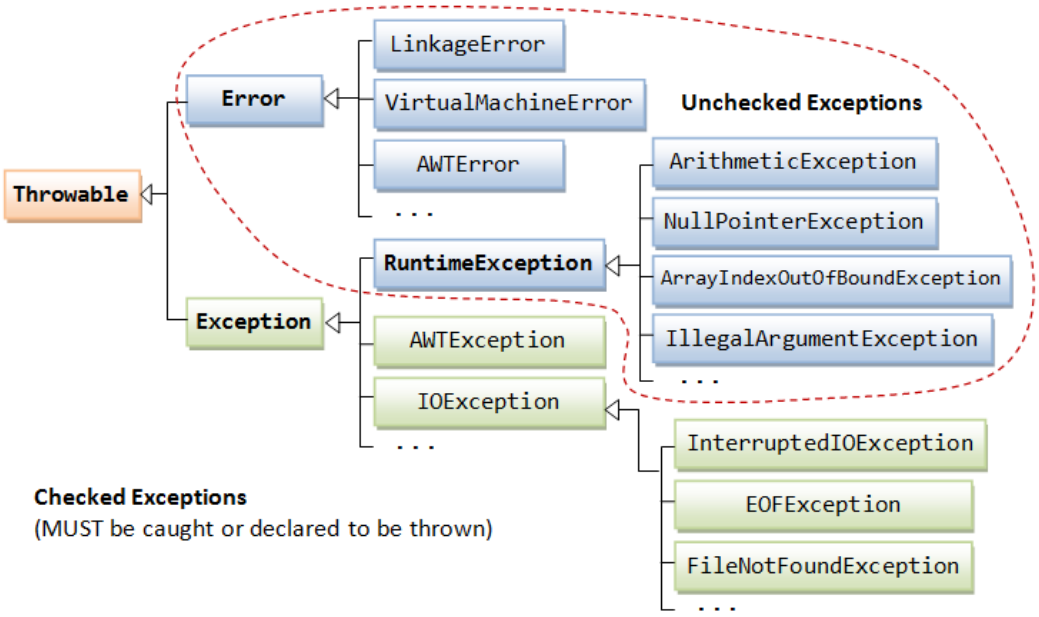
Exception Demo Arithmetic Exception

```
import java.util.*;

public class ExceptionDemo_131
{
      public static void main(String[] args)
      {
         Scanner scan = new Scanner(System.in);
         int age;

         try
         {
             System.out.print("\n\t Enter age :");
             age = scan.nextInt();

             System.out.println("\n\t Age = " + age);
         }
```

```
            catch(InputMismatchException e)
            {
                System.out.println("\n\t Exception Caught");
                System.out.println("\n\t Error : " + e);
            }
             System.out.println("\n\t End of Program");
        }
}
```

Exception Classes

The figure below shows the hierarchy of the `Exception` classes. The base class for all `Exception` objects is `java.lang.Throwable`, together with its two subclasses `java.lang.Exception` and`java.lang.Error`.



The `Error` class describes internal system errors (e.g., `VirtualMachineError`, `LinkageError`) that rarely occur. If such an error occurs, there is little that you can do and the program will be terminated by the Java runtime.

The `Exception` class describes the error caused by your program (e.g. `FileNotFoundException`, `IOException`). These errors could be caught and handled by your program (e.g., perform an alternate action or do a graceful exit by closing all the files, network and database connections).

In Java, exceptions are objects. When you throw an exception, you throw an object. You can't throw just any object as an exception, however -- only those objects whose classes descend from `Throwable`. `Throwable` serves as the base class for an entire family of classes, declared in `java.lang`, that your program can instantiate and throw.

`Throwable` has two direct subclasses, `Exception` and `Error`. Exceptions (members of the `Exception` family) are thrown to signal abnormal conditions that can often be handled by some catcher, though it's possible they may not be caught and therefore could result in a dead thread. Errors (members of the `Error` family) are usually thrown for more serious problems, such as `OutOfMemoryError`, that may not be so easy to handle. In general, code you write should throw only exceptions, not errors. `Errors` are usually thrown by the methods of the Java API, or by the Java virtual machine itself.

In addition to throwing objects whose classes are declared in `java.lang`, you can throw objects of your own design. To create your own class of throwable objects, you need only declare it as a subclass of some member of

the `Throwable` family. In general, however, the throwable classes you define should extend class `Exception`. They should be "exceptions."

Whether you use an existing exception class from `java.lang` or create one of your own depends upon the situation. In some cases, a class from `java.lang` will do just fine. For example, if one of your methods is invoked with an invalid argument, you could throw `IllegalArgumentException`, a subclass of `RuntimeException` in `java.lang`.

Advantages of Exceptions

Now that you know what exceptions are and how to use them, it's time to learn the advantages of using exceptions in your programs.

Advantage 1: Separating Error-Handling Code from "Regular" Code

Exceptions provide the means to separate the details of what to do when something out of the ordinary happens from the main logic of a program. In traditional programming, error detection, reporting, and handling often lead to confusing spaghetti code. For example, consider the pseudocode method here that reads an entire file into memory.

```
readFile {
    open the file;
    determine its size;
    allocate that much memory;
    read the file into memory;
    close the file;
}
```

At first glance, this function seems simple enough, but it ignores all the following potential errors.

1. What happens if the file can't be opened?
2. What happens if the length of the file can't be determined?
3. What happens if enough memory can't be allocated?
4. What happens if the read fails?
5. What happens if the file can't be closed?

To handle such cases, the `readFile` function must have more code to do error detection, reporting, and handling. Here is an example of what the function might look like.

```
errorCodeType readFile {
    initialize errorCode = 0;

    open the file;
    if (theFileIsOpen) {
        determine the length of the file;
        if (gotTheFileLength) {
            allocate that much memory;
            if (gotEnoughMemory) {
                read the file into memory;
                if (readFailed) {
                    errorCode = -1;
```

```
                }
            } else {
                errorCode = -2;
            }
        } else {
            errorCode = -3;
        }
        close the file;
        if (theFileDidntClose && errorCode == 0) {
            errorCode = -4;
        } else {
            errorCode = errorCode and -4;
        }
    } else {
        errorCode = -5;
    }
    return errorCode;
}
```

There's so much error detection, reporting, and returning here that the original seven lines of code are lost in the clutter. Worse yet, the logical flow of the code has also been lost, thus making it difficult to tell whether the code is doing the right thing: Is the file really being closed if the function fails to allocate enough memory? It's even more difficult to ensure that the code continues to do the right thing when you modify the method three months after writing it. Many programmers solve this problem by simply ignoring it — errors are reported when their programs crash.

Exceptions enable you to write the main flow of your code and to deal with the exceptional cases elsewhere. If the `readFile` function used exceptions instead of traditional error-management techniques, it would look more like the following.

```
readFile {
    try {
        open the file;
        determine its size;
        allocate that much memory;
        read the file into memory;
        close the file;
    } catch (fileOpenFailed) {
       doSomething;
    } catch (sizeDeterminationFailed) {
        doSomething;
    } catch (memoryAllocationFailed) {
        doSomething;
```

```
        } catch (readFailed) {
            doSomething;
        } catch (fileCloseFailed) {
            doSomething;
        }
    }
```

Note that exceptions don't spare you the effort of doing the work of detecting, reporting, and handling errors, but they do help you organize the work more effectively.

Advantage 2: Propagating Errors Up the Call Stack

A second advantage of exceptions is the ability to propagate error reporting up the call stack of methods. Suppose that the `readFile` method is the fourth method in a series of nested method calls made by the main program: `method1` calls `method2`, which calls `method3`, which finally calls `readFile`.

```
method1 {
    call method2;
}

method2 {
    call method3;
}

method3 {
    call readFile;
}
```

Suppose also that `method1` is the only method interested in the errors that might occur within `readFile`. Traditional error-notification techniques force `method2` and `method3` to propagate the error codes returned by `readFile` up the call stack until the error codes finally reach `method1`—the only method that is interested in them.

```
method1 {
    errorCodeType error;
    error = call method2;
    if (error)
        doErrorProcessing;
    else
        proceed;
}

errorCodeType method2 {
    errorCodeType error;
    error = call method3;
    if (error)
        return error;
    else
        proceed;
}

errorCodeType method3 {
    errorCodeType error;
    error = call readFile;
    if (error)
        return error;
    else
        proceed;
}
```

Recall that the Java runtime environment searches backward through the call stack to find any methods that are interested in handling a particular exception. A method can duck any exceptions thrown within it, thereby allowing a method farther up the call stack to catch it. Hence, only the methods that care about errors have to worry about detecting errors.

```
method1 {
    try {
        call method2;
    } catch (exception e) {
        doErrorProcessing;
    }
}
method2 throws exception {
```

```
        call method3;
    }

    method3 throws exception {
        call readFile;
    }
```

However, as the pseudocode shows, ducking an exception requires some effort on the part of the middleman methods. Any checked exceptions that can be thrown within a method must be specified in its `throws` clause.

Advantage 3: Grouping and Differentiating Error Types

Because all exceptions thrown within a program are objects, the grouping or categorizing of exceptions is a natural outcome of the class hierarchy. An example of a group of related exception classes in the Java platform are those defined in `java.io` –`IOException` and its descendants. `IOException` is the most general and represents any type of error that can occur when performing I/O. Its descendants represent more specific errors. For example, `FileNotFoundException` means that a file could not be located on disk.

A method can write specific handlers that can handle a very specific exception. The `FileNotFoundException` class has no descendants, so the following handler can handle only one type of exception.

```
    catch (FileNotFoundException e) {
        ...
    }
```

A method can catch an exception based on its group or general type by specifying any of the exception's superclasses in the `catch` statement. For example, to catch all I/O exceptions, regardless of their specific type, an exception handler specifies an `IOException` argument.

```
    catch (IOException e) {
        ...
    }
```

This handler will be able to catch all I/O exceptions, including `FileNotFoundException`, `EOFException`, and so on. You can find details about what occurred by querying the argument passed to the exception handler. For example, use the following to print the stack trace.

```
    catch (IOException e) {
        // Output goes to System.err.
        e.printStackTrace();
        // Send trace to stdout.
        e.printStackTrace(System.out);
    }
```

You could even set up an exception handler that handles any `Exception` with the handler here.

```
    // A (too) general exception handler
    catch (Exception e) {
        ...
    }
```

The `Exception` class is close to the top of the `Throwable` class hierarchy. Therefore, this handler will catch many other exceptions in addition to those that the handler is intended to catch. You may want to handle exceptions this way if all you want your program to do, for example, is print out an error message for the user and then exit.

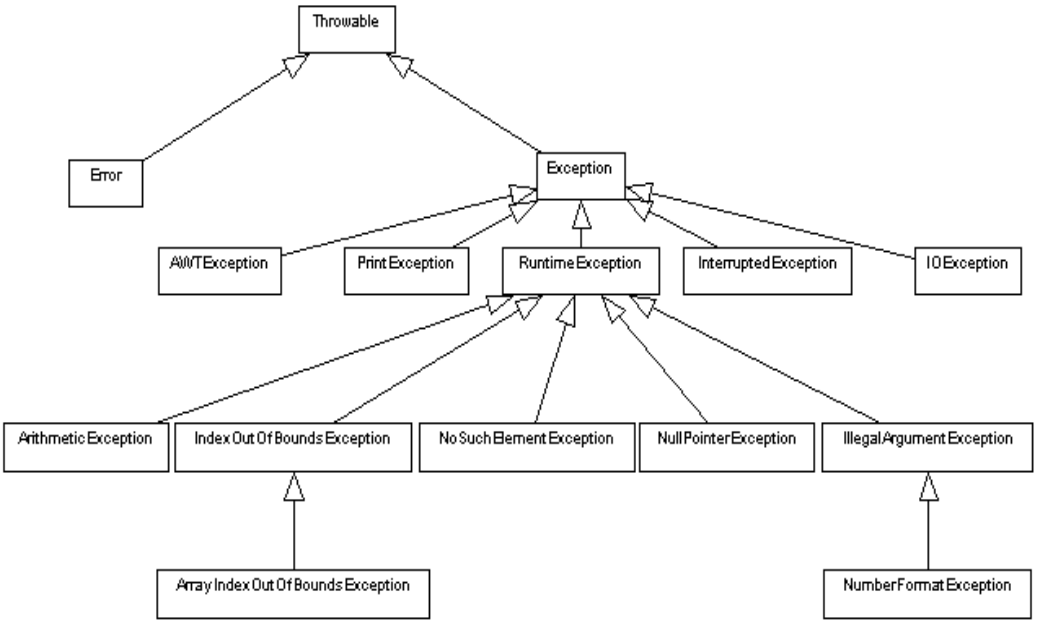
In most situations, however, you want exception handlers to be as specific as possible. The reason is that the first thing a handler must do is determine what type of exception occurred before it can decide on the best recovery strategy. In effect, by not catching specific errors, the handler must accommodate any possibility. Exception handlers that are too general can make code more error-prone by catching and handling exceptions that weren't anticipated by the programmer and for which the handler was not intended.

As noted, you can create groups of exceptions and handle exceptions in a general fashion, or you can use the specific exception type to differentiate exceptions and handle exceptions in an exact fashion.

Checked vs. Unchecked Exceptions

A checked exception is an exception that is typically a user error or a problem that cannot be foreseen by the programmer. These exceptions cannot simply be ignored at the time of compilation. These exceptions are explicitly handled in code itself with the help of try – catch blocks

Unchecked Exceptions are not essentially handled in the program code, instead the JVM handles such Exceptions. As opposed to checked exceptions, runtime exceptions are ignored at the time of compilation.



As illustrated, the subclasses of `Error` and `RuntimeException` are known as `unchecked exceptions`. These exceptions are not checked by the compiler, and hence, need not be caught or declared to be thrown in your program.

This is because there is not much you can do with these exceptions. For example, a "divide by 0" triggers an `ArithmeticException`, array index out-of-bound triggers an `ArrayIndexOutOfBoundException`, which are really programming logical errors that shall be been fixed in compiled-time, rather than leaving it to runtime exception handling.

All the other exceptions are called checked exceptions. They are checked by the compiler and must be caught or declared to be thrown.

Printing Exception

System.out.println(ex)

Prints the string representation of exception object. Prints the exception class name (java.lang.ArithmeticException) and also the exception message

System.out.println(ex.getMessage())

Prints exception message (Ex. / by zero) only indicating the cause of exception

e.printStackTrace()

Prints the exception class name with the message particulars and also the line number where the problem arises (traces the actual problem).

Common Exception Classes

NumberFormatException

- It is an unchecked exception thrown by **parseXXX()** methods when they are unable to format (convert) a string into a number.
- Sometimes, in Java coding, we get input (like from command-line arguments and text field) from the user in the form of string. To use the string in arithmetic operations, it must be converted (parsed) into data types. This is done by parseXXX() methods of wrapper classes.
- Object –> Throwable –> Exception –> RuntimeException –> NumberFormatException

Program N0.

Exception Demo

```
public class ExceptionDemo
{
	public static void main(String[] args)
	{
		String str = "onetwothree";
		int no;

		try
		{
		no = Integer.parseInt(str);
		System.out.println("\n\t no = " + no);
		}
		catch(NumberFormatException e)
		{
			System.out.println("\n\t Error :" +  e.getMessage());
		}
		System.out.println("\n\t End of Program");
	}
}
```

ArrayIndexOutOfBoundsException

Thrown by JVM when your code uses an array index, which is is outside the array's bounds. For example,

```
int[] anArray = new int[3];
System.out.println(anArray[3]);
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: 3
```

NullPointerException

Thrown by the JVM when your code attempts to use a null reference where an object reference is required. For example,

```
String[] strs = new String[3];
System.out.println(strs[0].length());
Exception in thread "main" java.lang.NullPointerException
```

ClassCastException

Thrown by JVM when an attempt is made to cast an object reference fails. For example,

```
Object o = new Object();
Integer i = (Integer)o;
Exception in thread "main" java.lang.ClassCastException: java.lang.Object cannot be
cast to java.lang.Integer
```

IllegalArgumentException

Thrown programmatically to indicate that a method has been passed an illegal or inappropriate argument. You could re-use this exception for your own methods.

IllegalStateException

Thrown programmatically when a method is invoked and the program is not in an appropriate state for that method to perform its task. This typically happens when a method is invoked out of sequence, or perhaps a method is only allowed to be invoked once and an attempt is made to invoke it again.

NoClassDefFoundError

Thrown by the JVM or class loader when the definition of a class cannot be found. Prior to JDK 1.7, you will see this exception call stack trace if you try to run a non-existent class. JDK 1.7 simplifies the error message to "Error: Could not find or load main class xxx".

Multiple Catch Blocks

It is possible to have more than one catch statement in the try-catch block

Program N0.

Exception Demo

```
import java.util.*;
```

```
public class ExceptionDemo
{
	public static void main(String[] args)
	{
		Scanner scan = new Scanner(System.in);
		int n1, n2, ans;

		try
		{
		  System.out.print("\n\t Enter Number 1 :");
		  n1 = scan.nextInt();
		  System.out.print("\n\t Enter Number 2 :");
		  n2 = scan.nextInt();
		  ans = n1/n2;
		  System.out.println("\n\t Answer  = " + ans);
	    }
	    catch(InputMismatchException e)
	    {
			System.out.println("\n\t Exception Caught");
			e.printStackTrace();
	    }
	    catch(ArithmeticException e)
	    {
			System.out.println("\n\t Can not / by zero");
	    }
	    catch(Exception e)
	    {
	    }

		System.out.println("\n\t End of Program");
	}
}
```

When an exception in the try block is generated, the Java treats the multiple catch Statements like cases in a switch statement. The first statement whose parameter matches with the exception object will be executed, and the remaining statements will be skipped.

Note: Java does not require any processing of the exception at all. We can simply have a catch statement with an empty block to avoid program abortion

Handling exceptions – Three styles

1. Using try-catch block; the robust way
2. Using throws in place of try-catch, not a robust way
3. To throw the exception object to the system using throw keyword, not a robust way

Exception Handling Operations

Five keywords are used in exception handling: `try`, `catch`, `finally`, `throws` and `throw` (take note that there is a difference between `throw` and `throws`).

Java's exception handling consists of three operations:

1. Declaring exceptions
2. Throwing an exception
3. Catching an exception

Declaring Exceptions

A Java method must declare in its signature the types of checked exception it may "throw" from its body, via the keyword "throws".

For example, suppose that `methodD()` is defined as follows:

```
public void methodD() throws XxxException, YyyException {
   // method body throw XxxException and YyyException
}
```

The method's signature indicates that running `methodD()` may encounter two checked exceptions: `XxxException` and `YyyException`. In other words, some of the abnormal conditions inside`methodD()` may trigger `XxxException` or `YyyException`.

Exceptions belonging to `Error`, `RuntimeException` and their *subclasses* need not be declared. These exceptions are called *unchecked exceptions* because they are not checked by the compiler.

Throwing an Exception

When a Java operation encounters an abnormal situation, the method containing the erroneous statement shall create an appropriate `Exception` object and throw it to the Java runtime via the statement "`throw XxxException`". For example,

```
public void methodD() throws XxxException, YyyException {   // method's signature
   // method's body
   ...
   ...

 // XxxException occurs
   if ( ... )
       throw new XxxException(...);   // construct an XxxException object and throw
                                          to JVM
...
   // YyyException occurs
   if ( ... )
      throw new YyyException(...);   // construct an YyyException object and throw
to JVM
   ...
}
```

Note that the keyword to declare exception in the method's signature is "`throws`" and the keyword to throw an exception object within the method's body is "`throw`".

Catching an Exception

When a method throws an exception, the JVM searches backward through the call stack for a matching exception handler. Each exception handler can handle one particular class of exception. An exception handler handles a specific class can also handle its subclasses. If no exception handler is found in the call stack, the program terminates.

For example, suppose `methodD()` declares that it may throw `XxxException` and `YyyException` in its signature, as follows:

```
public void methodD() throws XxxException, YyyException { ..... }
```

To use `methodD()` in your program (says in `methodC()`), you can either:

1. Wrap the call of `methodD()` inside a try-catch (or try-catch-finally) as follows. Each catch-block can contain an exception handler for one type of exception.

```
public void methodC() {  // no exception declared
   ......
   try {
      ......
      // uses methodD() which declares XxxException & YyyException
      methodD();
      ......
   } catch (XxxException ex) {
      // Exception handler for XxxException
      ......
   } catch (YyyException ex} {
      // Exception handler for YyyException
      ......
   } finally {   // optional
      // These codes always run, used for cleaning up
      ......
   }
   ......
}
```

2. Suppose that `methodC()` who calls `methodD()` does not wish to handle the exceptions (via a try-catch), it can declare these exceptions to be thrown up the call stack in its signature as follows:

```
public void methodC() throws XxxException, YyyException {   // for next higher-level method
to handle
   ...
   // uses methodD() which declares "throws XxxException, YyyException"
   methodD();   // no need for try-catch
   ...
}
```

In this case, if a `XxxException` or `YyyException` is thrown by `methodD()`, JVM will *terminate* `methodD()` as well as `methodC()` and pass the exception object up the call stack to the caller of `methodC()`.

Point 1: Exceptions must be declared

As an example, suppose that you want to use a `java.util.Scanner` to perform formatted input from a disk file. The signature of the `Scanner`'s constructor with a `File` argument is given as follows:

```
public Scanner(File source) throws FileNotFoundException;
```

The method's signature informs the programmers that an exceptional condition "file not found" may arise. By declaring the exceptions in the method's signature, programmers are made to aware of the exceptional conditions in using the method.

Point 2: Exceptions must be handled

If a method declares an exception in its signature, you cannot use this method without handling the exception - you can't compile the program.

Example 1: The program did not handle the exception declared, resutled in compilation error.

```
import java.util.Scanner;
import java.io.File;
public class ScannerFromFile {
   public static void main(String[] args) {
      Scanner in = new Scanner(new File("test.in"));
      // do something ...
   }
}
```

ERROR

ScannerFromFile.java:5: `unreported exception java.io.FileNotFoundException; must be caught or declared to be thrown`

```
Scanner in = new Scanner(new File("test.in"));
```

To use a method that declares an exception in its signature, you MUST either:

1. provide exception handling codes in a "`try-catch`" or "`try-catch-finally`" construct, or
2. if don't want handling the exception in the current method, but declare the exception to be thrown up the call stack for the next higher-level method to handle.

Example 2: Catch the exception via a "**`try-catch`**" (or "**`try-catch-finally`**") construct.

```
import java.util.Scanner;
import java.io.File;
import java.io.FileNotFoundException;
public class ScannerFromFileWithCatch {
   public static void main(String[] args) {
      try {
         Scanner in = new Scanner(new File("test.in"));
         // do something if no exception ...
         // you main logic here in the try-block
      }
      catch (FileNotFoundException ex)
      {
         // error handling separated from the main logic
         ex.printStackTrace();            // print the stack trace
      }
   }
}
```

If the file cannot be found, the exception is caught in the catch-block. In this example, the error handler simply prints the *stack trace*, which provides useful information for debugging. In some situations, you may need to perform some

clean-up operations, or open another file instead. Take note that the main logic in the try-block is separated from the error handling codes in the catch-block.

Example 3: You decided not to handle the exception in the current method, but throw the exception up the call stack for the next higher-level method to handle.

```
import java.util.Scanner;
import java.io.File;
import java.io.FileNotFoundException;
public class ScannerFromFileWithThrow {
   public static void main(String[] args) throws FileNotFoundException {
                                    // to be handled by next higher-level method
      Scanner in = new Scanner(new File("test.in"));
                                   // this method may throw FileNotFoundException
      // main logic here ...
   }
}
```

In this example, you decided not to handle the `FileNotFoundException` thrown by the `Scanner(File)` method (with `try-catch`). Instead, the caller of `Scanner(File)` - the `main()` method - declares in its signature "`throws FileNotFoundException`", which means that this exce ption will be thrown up the call stack, for the next higher-level method to handle. In this case, the next higher-level method of `main()` is the JVM, which simply terminates the program and prints the stack trace.

Point 3: Main logic is separated from the exception handling codes

As shown in Example 2, the main logic is contained in the try-block, while the exception handling codes are kept in the catch-block(s) separated from the main logic. This greatly improves the readability of the program.

For example, a Java program for file processing could be as follows:

```
try {
   // Main logic here
   open file;
   process file;
   ......
} catch (FileNotFoundException ex) {    // Exception handlers below
   // Exception handler for "file not found"
} catch (IOException ex) {
   // Exception handler for "IO errors"
} finally {
  close file;        // always try to close the file
}
```

Throws Keyword

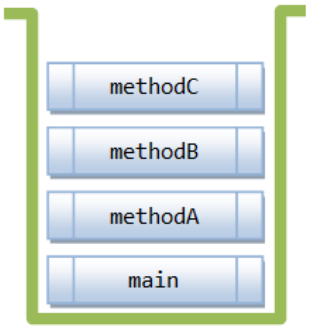
What if I really don't care about the exceptions

Certainly not advisable other than writing toy programs. But to bypass the compilation error messages triggered by methods declaring unchecked exceptions, you could declare "`throws Exception`" in your `main()` (and other methods), as follows:

```
public static void main(String[] args) throws Exception {   // throws all subclass of Exception to
JRE
   Scanner in = new Scanner(new File("test.in"));    // declares "throws
FileNotFoundException"
   ......
   // other exceptions
}
```

Method Call Stack

A typical application involves many levels of method calls, which is managed by a so-called *method call stack*. A *stack* is a last-in-first-out queue. In the following example, `main()` method invokes `methodA()`; `methodA()` calls `methodB()`; `methodB()` calls `methodC()`.



Method Call Stack
(Last-in-First-out Queue)

```
public class MethodCallStackDemo {
   public static void main(String[] args) {
      System.out.println("Enter main()");
      methodA();
      System.out.println("Exit main()");
   }

   public static void methodA() {
      System.out.println("Enter methodA()");
      methodB();
      System.out.println("Exit methodA()");
   }

   public static void methodB() {
      System.out.println("Enter methodB()");
      methodC();
      System.out.println("Exit methodB()");
```

```
   }

   public static void methodC() {
      System.out.println("Enter methodC()");
      System.out.println("Exit methodC()");
   }
}
Enter main()
Enter methodA()
Enter methodB()
Enter methodC()
Exit methodC()
Exit methodB()
Exit methodA()
Exit main()
```

As seen from the output, the sequence of events is:

1. JVM invoke the `main()`.
2. `main()` pushed onto call stack, before invoking `methodA()`.
3. `methodA()` pushed onto call stack, before invoking `methodB()`.
4. `methodB()` pushed onto call stack, before invoking `methodC()`.
5. `methodC()` completes.
6. `methodB()` popped out from call stack and completes.
7. `methodA()` popped out from the call stack and completes.
8. `main()` popped out from the call stack and completes. Program exits.

Suppose that we modify `methodC()` to carry out a "divide-by-0" operation, which triggers a `ArithmeticException`:

```
public static void methodC() {
   System.out.println("Enter methodC()");
   System.out.println(1 / 0);   // divide-by-0 triggers an ArithmeticException
   System.out.println("Exit methodC()");
}
```

The exception message clearly shows the *method call stack trace* with the relevant statement line numbers:

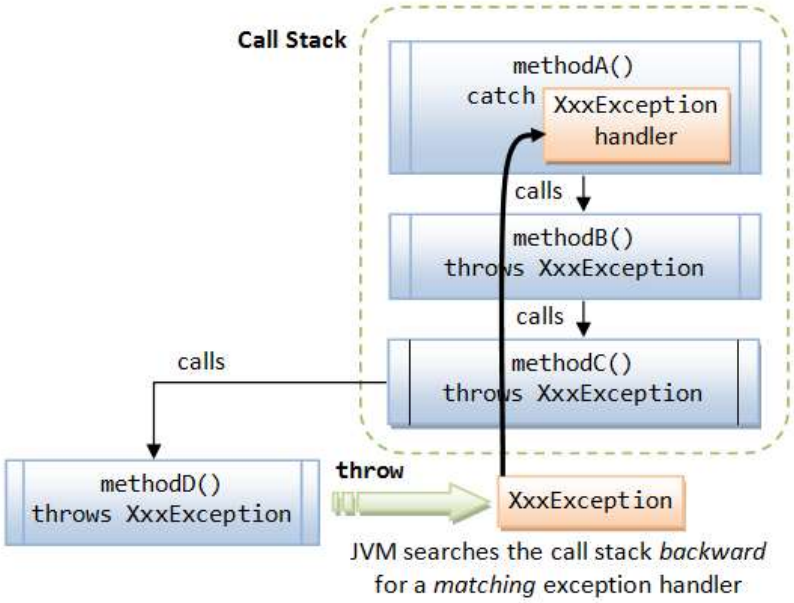
```
Enter main()
Enter methodA()
Enter methodB()
Enter methodC()
Exception in thread "main" java.lang.ArithmeticException: / by zero
        at MethodCallStackDemo.methodC(MethodCallStackDemo.java:22)
        at MethodCallStackDemo.methodB(MethodCallStackDemo.java:16)
```

```
        at MethodCallStackDemo.methodA(MethodCallStackDemo.java:10)
        at MethodCallStackDemo.main(MethodCallStackDemo.java:4)
```

`MethodC()` triggers an `ArithmeticException`. As it does not handle this exception, it popped off from the call stack immediately. `MethodB()` also does not handle this exception and popped off the call stack.

So does `methodA()` and `main()` method. The `main()` method passes back to JVM, which abruptly terminates the program and print the call stack trace, as shown.

Exception & Call Stack



When an exception occurs inside a Java method, the method creates an `Exception` object and passes the `Exception` object to the JVM (in Java term, the method "`throw`" an `Exception`).

The `Exception`object contains the type of the exception, and the state of the program when the exception occurs. The JVM is responsible for finding an exception handler to process the `Exception` object. It searches backward through the call stack until it finds a matching exception handler for that particular class of `Exception` object (in Java term, it is called "`catch`" the `Exception`). If the JVM cannot find a matching exception handler in all the methods in the call stack, it terminates the program.

This process is illustrated as follows. Suppose that `methodD()` encounters an abnormal condition and throws a `XxxException` to the JVM. The JVM searches backward through the call stack for a matching exception handler. It finds `methodA()` having a `XxxException` handler and passes the exception object to the handler. Notice that `methodC()` and `methodB()` are required to declare "`throws XxxException`" in their method signatures in order to compile the program.

try-with-resources structure

So far you have been familiar with the `try-catch-finally` structure. Now I'm about to tell you the advanced version of exception handling in Java - it is the **`try-with-resources`** structure which was added to the Java language from Java SE 7.

Let's look at a typical try-catch-finally example I showed you previously:

```
FileWriter writer = null;
try {
      writer = new FileWriter("Name.txt");
      writer.write("Hello ");
      writer.close();
} catch (IOException e) {
      e.printStackTrace();
} finally {
      if (writer != null) {
            try {
                  writer.close();
```

```
            } catch (IOException ce) {
                  ce.printStackTrace();
            }
      }
}
```

The `finally` block is usually used to close a resource such as a file, a network connection, a database connection and the like. This pattern is repeated again and again so Java 7 makes our lives easier by enhancing the exception handling with the introduction of `try-with-resources` structure.

The above code can be re-written using the `try-with-resources` construct as follows:

```
try (FileWriter writer = new FileWriter("Name.txt")) {
      writer.write("Hello ");
      writer.close();
} catch (IOException e) {
      e.printStackTrace();
}
```

With this new structure, we don't have to explicitly close the resource used by the `finally` block. Instead, the Java compiler will figure it out and automatically adds code to close the resource for us.

Well, the secret lies in the **`AutoCloseable`** interface that defines only a single method:

```
public void close();
```

So when a resource used by the `try` block implements this interface, the compiler knows that it's safe to call the **`close()`** method on the resource object.

That means the `try-with-resources` structure works only with `AutoCloseable's` implementations. And fortunately, Java 7 refactors almost resource-like classes to implement this interface to support programmers.

Thanks to the `try-with-resources` construct that brings us the following benefits:

- We can write more compact code as eliminating the finally block. This saves time.
- We can write more safe and efficient code as if we forget to close a resource, the compiler does the work for us behind the scenes.

Using a database connection within a **`try-catch-finally`** structure:

```
Connection conn = null;
try {
   String dbURL = "jdbc:oracle:thin:tiger/scott@localhost:1521:DB";
   conn = DriverManager.getConnection(dbURL);
   // execute SQL statements
} catch (SQLException ex) {
   ex.printStackTrace();
} finally {
   try {
      if (conn != null && !conn.isClosed()) {
         conn.close();
      }
   } catch (SQLException ex) {
      ex.printStackTrace();
   }
}
```

It is now more compact with `try-with-resources` version:

```
String dbURL = "jdbc:oracle:thin:tiger/scott@localhost:1521:DB";
try (Connection conn = DriverManager.getConnection(dbURL)) {
      // execute SQL statements
} catch (SQLException ex) {
      ex.printStackTrace();
}
```

NOTE: we can use initialize multiple resources in the `try` block and the compiler is smart enough to close them all. Here's an example that copies one file to another using the `try-catch-finally` fashion:

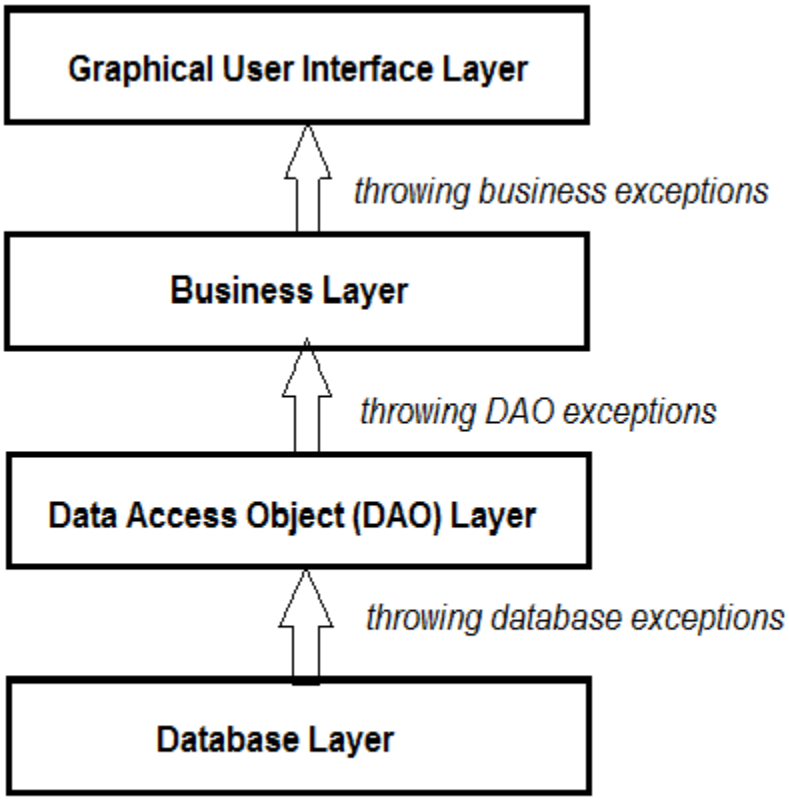
```
public void copyFile(File sourceFile, File destFile)
        throwsIOException {
        FileChannel sourceChannel = null;
        FileChannel destChannel = null;
    try{
        sourceChannel = newFileInputStream(sourceFile).getChannel();
        destChannel = newFileOutputStream(destFile).getChannel();
        sourceChannel.transferTo(0, sourceChannel.size(), destChannel);
    } finally{
        if(sourceChannel != null) {
            sourceChannel.close();
        }
        if(destChannel != null) {
            destChannel.close();
        }
    }
}
```

And now with the try-with-resources fashion:

```
public void copyFile(File sourceFile, File destFile)
        throwsIOException {
    try(
        FileChannel sourceChannel = newFileInputStream(sourceFile).getChannel();
        FileChannel destChannel = newFileOutputStream(destFile).getChannel();
    ) {
        sourceChannel.transferTo(0, sourceChannel.size(), destChannel);
    }
}
```

Exception Chaining?

Basically, exception chaining is the process of re-throwing multiple exceptions across different abstraction layers of a program. The key principle here is that, these exceptions are chained together to maintain the stack trace from the exception at the lowest layer to the one at the highest layer. The following picture illustrates this concept visually:



Java Exception Chaining Concept

As you can see, each abstraction layer defines its own exception classes. When code in a layer throws an exception, the higher layer re-throws it under a new type of exception which corresponds to the abstraction level of that layer. In turn, the next higher layer re-throws the exception under its own type of exception, and so on. This process continues until a layer handles the exception instead of re-throwing. During this chaining process, the higher exception always wraps the lower exception as its cause. Therefore, when an exception occurs, the programmer has a complete stack trace of the exceptions, which is very helpful for debugging.

* Why is Exception Chaining?

The main purpose of exception chaining is to preserve the original exception when it propagates across multiple logical layers in a program. This is very helpful for the debugging process when an exception is thrown, as the programmer can analyze the full stack trace of the exceptions.

In addition, exception chaining also helps promoting abstraction among logical layers in a program, as each layer defines its own exceptions which are specific for that layer. For example, the `StudentBusiness`class throws `StudentException` would be more meaningful than `SQLException`, right?

You know, exception chaining is sometimes referred as *exception propagation*, as when a layer throws an exception, the exception propagates through higher layers until a layer handles it such as displaying a message/warning to the user.

* How to Chain Exceptions Together?

Let's consider the following code example:

```
public void setBirthday(String birthDate) throws InvalidBirthdayException {
      DateFormat formatter = new SimpleDateFormat();
      try {
            Date birthday = formatter.parse(birthDate);
      } catch (ParseException ex) {
            throw new InvalidBirthdayException("Date of birth is invalid", ex);
      }
}
```

As you can see in the `setBirthday()` method, the `ParseException` is re-thrown under a new exception called `InvalidBirthdayException`. The `ParseException` is chained via the constructor of `InvalidBirthdayException` class:

```
throw new InvalidBirthdayException("Date of birth is invalid", ex);
```

This custom exception is implemented as following:

```
public class InvalidBirthdayException extends Exception {
      public InvalidBirthdayException(String message, Throwable cause) {
            super(message, cause);
      }
}
```

You can notice that, this constructor invokes its super's constructor:

```
super(message, cause);
```

The supertypes of all exceptions `Throwable` and `Exception` implement this constructor, so any custom exceptions can call it. The origin exception (the cause) is passed to the being-created exception via its constructor.

Remember that the `Exception` class provides the following constructors that help chaining an exception:

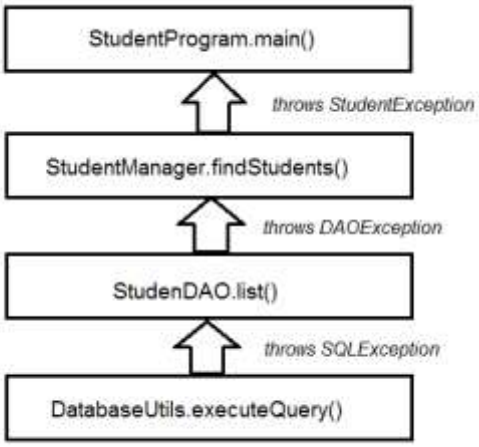
- `Exception(Throwable cause)`
- `Exception(String message, Throwable cause)`

Besides chaining an exception via constructor, you can also chain an exception through the following `Throwable`'s method:

```
public Throwable initCause(Throwable cause)
```

That's how exceptions are chained together.

Let's see another example which is illustrated by the following picture:



Exceptions Chaining Example

And following is source code of each class.

DAOException.java:

```
public class DAOException extends Exception {
	public DAOException(String message, Throwable cause) {
		super(message, cause);
	}
}
```

StudentException.java:

```
public class StudentException extends Exception {
	public StudentException(String message) {
		super(message);
	}
	public StudentException(String message, Throwable cause) {
		super(message, cause);
	}
}
```

DatabaseUtils.java:

```
import java.sql.*;
public class DatabaseUtils {
	public static void executeQuery(String sql) throws SQLException {
		throw new SQLException("Syntax Error");
	}
}
```

StudentDAO.java:

```
import java.sql.*;
public class StudentDAO {
	public void list() throws DAOException {
```

```
            try {
                  DatabaseUtils.executeQuery("SELECT");
            } catch (SQLException ex) {
                  throw new DAOException("Error querying students from database", ex);
            }
      }
}
```

StudentManager.java:

```
public class StudentManager {
      private StudentDAO dao;
      public StudentManager(StudentDAO dao) {
            this.dao = dao;
      }
      public void findStudents(String keyword) throws StudentException {
            try {
                  dao.list();
            } catch (DAOException ex) {
                  throw new StudentException("Error finding students", ex);
            }
      }
}
```

StudentProgram.java:

```
public class StudentProgram {
      public static void main(String[] args) {
            StudentDAO dao = new StudentDAO();
            StudentManager manager = new StudentManager(dao);
            try {
                  manager.findStudents("Tom");
            } catch (StudentException ex) {
ex.printStackTrace();
            }
      }

}
```

Run the `StudentProgram` and you should see the following output:

```
StudentException: Error finding students
       at StudentManager.findStudents(StudentManager.java:13)
       at StudentProgram.main(StudentProgram.java:9)
Caused by: DAOException: Error querying students from database
       at StudentDAO.list(StudentDAO.java:11)
       at StudentManager.findStudents(StudentManager.java:11)
       ... 1 more
Caused by: java.sql.SQLException: Syntax Error
       at DatabaseUtils.executeQuery(DatabaseUtils.java:5)
       at StudentDAO.list(StudentDAO.java:8)
       ... 2 more
```

You see? The printed exception stack trace reveals an exception propagates from the `DatabaseUtils` layer up to the `StudentProgram` layer in which the exception is handled by printing this trace.

try-catch-finally

The syntax of try-catch-finally is:

```
try {
    // main logic, uses methods that may throw Exceptions
    ......
} catch (Exception1 ex) {
    // error handler for Exception1
    ......
} catch (Exception2 ex) {
    // error handler for Exception1
    ......
} finally {      // finally is optional
    // clean up codes, always executed regardless of exceptions
    ......
}
```

If no exception occurs during the running of the try-block, all the catch-blocks are skipped, and finally-block will be executed after the try-block. If one of the statements in the try-block throws an exception, the Java runtime ignores the rest of the statements in the try-block, and begins searching for a matching exception handler. It matches the exception type with each of the catch-blocks sequentially.

If a catch-block catches that exception class or catches a *superclass* of that exception, the statement in that catch-block will be executed. The statements in the finally-block are then executed after that catch-block. The program continues into the next statement after the try-catch-finally, unless it is pre-maturely terminated or branch-out.

If none of the `catch`-block matches, the exception will be passed up the call stack. The current method executes the `finally` clause (if any) and popped off the call stack. The caller follows the same procedures to handle the exception.

The `finally` block is almost certain to be executed, regardless of whether or not exception occurs (unless JVM encountered a severe error or a `System.exit()` is called in the `catch` block).

Example 1

```
import java.util.Scanner;
import java.io.File;
import java.io.FileNotFoundException;
public class TryCatchFinally {
   public static void main(String[] args) {
```

```
      try {          // main logic
         System.out.println("Start of the main logic");
         System.out.println("Try opening a file ...");
         Scanner in = new Scanner(new File("test.in"));
         System.out.println("File Found, processing the file ...");
         System.out.println("End of the main logic");
      } catch (FileNotFoundException ex) {     // error handling separated from the main logic
         System.out.println("File Not Found caught ...");
      } finally {    // always run regardless of exception status
         System.out.println("finally-block runs regardless of the state of
exception");
      }
      // after the try-catch-finally
      System.out.println("After try-catch-finally, life goes on...");
   }
}
```

This is the output when the `FileNotFoundException` triggered:

```
Start of the main logic
Try opening a file ...
File Not Found caught ...
finally-block runs regardless of the state of exception
After try-catch-finally, life goes on...
```

This is the output when no exception triggered:

```
Start of the main logic
Try opening a file ...
File Found, processing the file ...
End of the main logic
finally-block runs regardless of the state of exception
After try-catch-finally, life goes on..
```

try-catch-finally

1. A try-block must be accompanied by at least one catch-block or a finally-block.
2. You can have multiple catch-blocks. Each catch-block catches only one type of exception.
3. A catch block requires one argument, which is a `throwable` object (i.e., a subclass of `java.lang.Throwable`), as follows:

```
catch (AThrowableSubClass aThrowableObject) {
   // exception handling codes
}
```

You can use the following methods to retrieve the type of the exception and the state of the program from the `Throwable` object:

`printStackTrace ()`: Prints this `Throwable` and its call stack trace to the standard error stream `System.err`. The first line of the outputs contains the result of `toString()`, and the remaining lines are the stack trace. This is the most common handler, if there is nothing better that you can do. For example,

```
try {
   Scanner in = new Scanner(new File("test.in"));
   // process the file here
   ......
} catch (FileNotFoundException ex) {
   ex.printStackTrace();
}
```

You can also use `printStackTrace(PrintStream s)` or `printStackTrace(PrintWriter s)`.

- **`getMessage()`:** Returns the `message` specified if the object is constructed using constructor `Throwable(String message)`.
- **`toString()`:** Returns a short description of this `Throwable` object, consists of the name of the class, a colon `':'`, and a message from `getMessage()`.
- A catch block catching a specific exception class can also catch its *subclasses*. Hence, `catch(Exception ex) {...}` catches all kinds of exceptions. However, this is not a good practice as the exception handler that is too general may unintentionally catches some subclasses' exceptions it does not intend to.
- The order of catch-blocks is important. A subclass must be caught (and placed in front) before its superclass. Otherwise, you receive a compilation error "exception `XxxException` has already been caught".
- The finally-block is meant for cleanup code such as closing the file, database connection regardless of whether the try block succeeds. The finally block is always executed (unless the catch-block pre-maturely terminated the current method).

Program N0. **Finally Block**

```
public class ExceptionDemo
{
	public static void main(String[] args)
	{
		String str = "onetwothree";
		int no;

		try
		{
		no = Integer.parseInt(str);
		System.out.println("\n\t no = " + no);
		}
		catch(NumberFormatException e)
```

```
            {
                  System.out.println("\n\t Error :" +
                e.getMessage());
            }
            finally
            {
                  System.out.println("\n\t End of Program");
            }

      }
}
```

Overriding and Overloading Methods

An overriding method must have the same argument list and return-type (or subclass of its original from JDK 1.5). An overloading method must have different argument list, but it can have any return-type.

An overriding method cannot have more restricted access. For example, a method with `protected` access may be overridden to have protected or public access but not `private` or default access. This is because an overridden method is considered to be a replacement of its original, hence, it cannot be more restrictive.

An overriding method cannot declare exception types that were not declared in its original. However, it may declare exception types are the same as, or subclass of its original. It needs not declare all the exceptions as its original. It can throw fewer exceptions than the original, but not more.

An overloading method must be differentiated by its argument list. It cannot be differentiated by the return-type, the exceptions, and the modifier, which is illegal. It can have any return-type, access modifier, and exceptions, as long as it can be differentiated by the argument list.

Creating Your Own Exception Classes

You should try to reuse the `Exception` classes provided in the JDK, e.g., `IndexOutOfBoundException`, `ArithmeticException`, `IOException`, and `IllegalArugmentException`. But you can always create you own `Exception` classes by extending from the class `Exception` or one of its subclasses.

Note that `RuntimeException` and its subclasses are not checked by the compiler and need not be declared in the method's signature. Therefore, use them with care, as you will not be informed and may not be aware of the exceptions that may occur by using that method (and therefore do not have the proper exception handling codes) – a bad software engineering practice.

Example

```
// Create our own exception class by subclassing Exception. This is a checked exception
public class MyMagicException extends Exception {
   public MyMagicException(String message) {  //constructor
      super(message);
   }
}
public class MyMagicExceptionTest {
   // This method "throw MyMagicException" in its body.
  // MyMagicException is checked and need to be declared in the method's signature
   public static void magic(int number) throws MyMagicException {
      if (number == 8) {
         throw (new MyMagicException("you hit the magic number"));
      }
      System.out.println("hello");   // skip if exception triggered
   }

   public static void main(String[] args) {
      try {
         magic(9);    // does not trigger exception
         magic(8);    // trigger exception
      } catch (MyMagicException ex) {    // exception handler
         ex.printStackTrace();
      }
   }
}
```

The output is as follows:

```
hello
MyMagicException: you hit the magic number
```

```
at MyMagicExceptionTest.magic(MyMagicExceptionTest.java:6)
at MyMagicExceptionTest.main(MyMagicExceptionTest.java:14)
```

Program NO.

User Defined Exception

```
import java.util.*;

class InvalidNo extends Exception
{
	public InvalidNo(String msg)
	{
		super(msg);
	}
}

public class ExceptionDemo
{
	public static void main(String[] args)
	{
		Scanner scan = new Scanner(System.in);

		try
		{
			int no;
			System.out.print("\n\t Enter number :");
			no = scan.nextInt();

			if(no>=0 && no<=9)
			{
				System.out.println("\n\t No = " + no);
			}
			else
			{
				throw new InvalidNo("No is Not Valid");
			}
		}
		catch(InvalidNo e)
		{
			System.out.println("\n\t Error = " + e.getMessage());
		}
		catch(InputMismatchException e)
		{
			System.out.println("\n\t Error = " + e);
		}
	}
}
```