

11. EXCEPTION AND EXCEPTION HANDLER



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Outline


1. Exceptions
2. Catching and handling exceptions
3. Exception delegation
4. User-defined exceptions

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1.1. What is exception?

- Exception = Exceptional event
- Definition: An exception is an event that occurs in the **execution** of a program and it **breaks** the expected flow of the program.

Example: $4/0 =$ 

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1.1. What is exception? (2)

- Exception is an particular error
 - Unexpected results
- When an exception occurs, if it is not handled, the program will exit immediately and the control is returned to the OS

```
float number1, number2;  
//input number1, number2;  
float division = number1 / number2;
```

No handler exists

EXIT

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1.2. Classical Error Handler

- Writing handling codes where errors occur
 - Making programs more complex
 - Not always have enough information to handle
 - Some errors are not necessary to handle
- Sending status to upper levels
 - Via arguments, return values or global variables (flag)
 - Easy to mis-understand
 - Still hard to understand



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Example

```
int devide(int num, int denom, int *error)
{
    if (denom != 0){
        *error = 0;
        return num/denom;
    } else {
        *error = 1;
        return 0;
    }
}
```



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Disadvantages

- Difficult to control all cases
 - Arithmetic errors, memory errors,...
- Developers often forget to handle errors
 - Human
 - Lack of experience, deliberately ignore



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Outline

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- ➔ 2. Catching and handling exceptions
3. Exception delegation
4. User-defined exceptions



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2.1. Goals of exception handling

- Making programs more reliable, avoiding unexpected termination
- Separating blocks of code that might cause exceptions and blocks of code that handle exceptions

```
.....
IF B IS ZERO GO TO ERROR
C = A/B
PRINT C
GO TO EXIT
```

```
ERROR:
  DISPLAY "DIVISION BY ZERO"
```

```
EXIT:
  END
```

} Error handling block

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Separating code

- Classic programming: `readFile()` function: not separate the main logic processing and error handling.

```
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;
            }
        }
    }
}
```

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Classic Programming

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

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Exception Handling

- Exception mechanism allows focusing on writing code for the main thread and then handling exception in another place

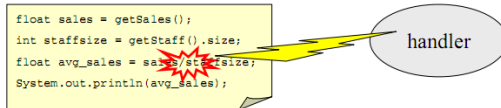
```
readFile() {
    try {
        open the file;
        determine its size;
        allocate that much memory;
        read the file into memory;
        close the file;
    } catch (fileOpenFailed) {
        doSomething;
    } catch (sizeDeterminationFailed) {
        doSomething;
    } catch (memoryAllocationFailed)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

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2.2. Models for handling exceptions

- Object oriented approach
 - Packing unexpected conditions in **an object**
 - When an exception occurs, the object corresponding to the exception is created and stores all the detailed information about the exception
 - Providing an efficient mechanism in handling errors
 - Separating irregular control threads with regular threads

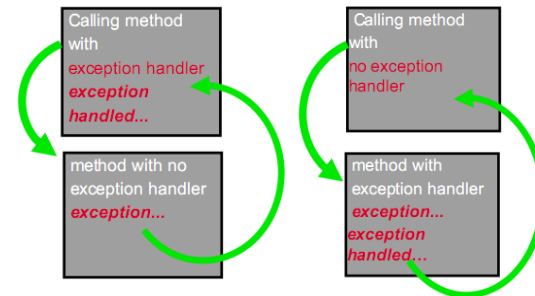


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2.2. Models for handling exceptions (2)

- Exceptions need to be handled at the method that causes the exceptions or delegated to its caller method

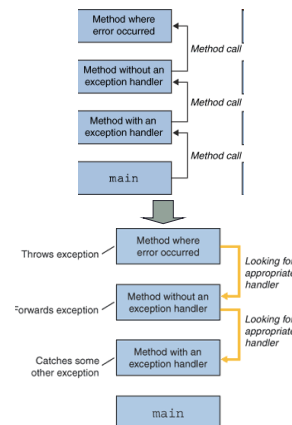


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2.3. Exception handling in Java

- Java has a strong mechanism for handling exceptions
- Exception handling in Java is done via object-oriented model:
 - All the exceptions are representations of a class **Throwable** or **its child classes**
 - These objects must send the information of exceptions (type and status of the program) from the exceptions place to where they are controlled/handled



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2.3. Exception handling in Java (2)

- Key words
 - **try**
 - **catch**
 - **finally**
 - **throw**
 - **throws**

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2.3.1. try/catch block

- try ... catch block: Separating the regular block of program and the block for handling exceptions
- try {...}: Block of code that might cause exceptions
- catch() {...}: Catching and handling exceptions

```
try {
    // Code block that might cause exception
}
catch (ExceptionType e) {
    // Handling exception
}
```

□ ExceptionType is a descendant of the Throwable

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Example of not handling exceptions

```
class NoException {
    public static void main(String args[]) {
        String text = args[0];
        System.out.println(text);
    }
}
```



```
D:\FIT-HUT\Lectures\OOP\OOP-Java\Demo>java NoException
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: 0
    at NoException.main(NoException.java:3)
D:\FIT-HUT\Lectures\OOP\OOP-Java\Demo>
```

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Example of handling exceptions

```
class ArgExceptionDemo {
    public static void main(String args[]) {
        try {
            String text = args[0];
            System.out.println(text);
        }
        catch (Exception e) {
            System.out.println("Hay nhap tham so khi chay!");
        }
    }
}
```

```
D:\FIT-HUT\Lectures\OOP\OOP-Java\Demo>java ArgExceptionDemo
Hay nhap tham so khi chay!
D:\FIT-HUT\Lectures\OOP\OOP-Java\Demo>_
```

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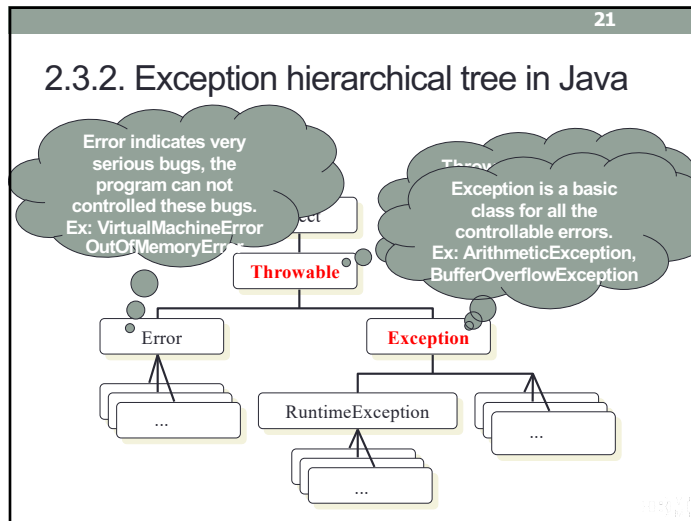
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Example of division by 0

```
public class ChiaCho0Demo {
    public static void main(String args[]){
        try {
            int num = calculate(9,0);
            System.out.println(num);
        }
        catch (Exception e) {
            System.err.println("Co loi xay ra: " + e.toString());
        }
    }
    static int calculate(int no, int noi){
        int num = no / noi;
        return num;
    }
}
```

```
Co loi xay ra: java.lang.ArithmeticException: / by zero
Press any key to continue . . .
```

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a. Class Throwable

- A variable of type `String` to store detailed information about exceptions that already occurred
- Some basic functions
 - `new Throwable(String s)`: Creates an exception and the exception information is `s`
 - `String getMessage()`: Get exception information
 - `String toString()`: Brief description of exceptions
 - `void printStackTrace()`: Print out all the involving information of exceptions (name, type, location...)
 - ...

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```

public class StckExceptionDemo {
    public static void main(String args[]){
        try {
            int num = calculate(9,0);
            System.out.println(num);
        }
        catch(Exception e) {
            System.err.println("Co loi xay ra : "
                               + e.getMessage());
            e.printStackTrace();
        }
    }
    static int calculate(int no, int nol) {
        int num = no / nol;
        return num;
    }
}
  
```

Co loi xay ra : / by zero
 java.lang.ArithmeticException: / by zero
 at StckExceptionDemo.calculate(StckExceptionDemo.java:14)
 at StckExceptionDemo.main(StckExceptionDemo.java:4)
 Press any key to continue . . .

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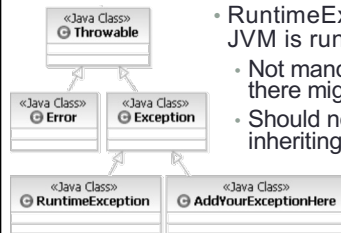
b. Class Error

- Contains critical and unchecked exceptions (unchecked exception) because it might occur at many parts of the program.
- Is called un-recoverable exception
- Do not need to check in your Java source code
- Child classes:
 - `VirtualMachineError`: `InternalError`, `OutOfMemoryError`, `StackOverflowError`, `UnknownError`
 - `ThreadDeath`
 - `LinkageError`:
 - `IncompatibleClassChangeError`
 - `AbstractMethodError`, `InstantiationError`, `NoSuchFieldError`, `NoSuchMethodError`...
 - ...
- ...

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c. Class Exception

- Has exception types that should/must be caught and handled or delegated.
- Developers might create their own exceptions by inheriting from Exception
- RuntimeException might appear while JVM is running
 - Not mandatory to catch exceptions even there might be errors
 - Should not write your own exception inheriting from this class



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Some derived classes of Exception

- ClassNotFoundException, SQLException
- java.io.IOException:
 - FileNotFoundException, EOFException...
- RuntimeException:
 - NullPointerException, BufferOverflowException
 - ClassCastException, ArithmeticException
 - IndexOutOfBoundsException:
 - ArrayIndexOutOfBoundsException,
 - StringIndexOutOfBoundsException...
 - IllegalArgumentException:
 - NumberFormatException, InvalidParameterException...
- ...

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Example of IOException

```

import java.io.InputStreamReader;
import java.io.IOException;
public class HelloWorld{
    public static void main(String[] args) {
        InputStreamReader isr = new
            InputStreamReader(System.in);

        try {
            System.out.print("Nhap vao 1 ky tu: ");
            char c = (char) isr.read();
            System.out.println("Ky tu vua nhap: " + c);
        } catch (IOException ioe) {
            ioe.printStackTrace();
        }
    }
}
  
```

Nhap vao 1 ky tu: b
 Ky tu vua nhap: b
 Press any key to continue . . .

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2.3.3. Nested try – catch blocks

- A small part of a code block causes an error, but the whole block cause another error → Need to have nested exception handlers.
- When there are nested try blocks, the inner try block will be done first.

```

try {
    // May cause IOException
    try {
        // May cause NumberFormatException
    }
    catch (NumberFormatException e1) {
        // Handle NumberFormatException
    }
    catch (IOException e2) {
        // Handle IOException
    }
}
  
```

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2.3.4. Multiple catch block

- A block of code might cause more than one exception
→ Need to use multiple catch block.

```
try {
    // May cause multiple exception
} catch (ExceptionType1 e1) {
    // Handle exception 1
} catch (ExceptionType2 e2) {
    // Handle exception 2
} ...
```


- **ExceptionType1** must be a derived class or an level-equivalent class of the class **ExceptionType2** (in the inheritance hierarchy tree)

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- **ExceptionType1** must be a derived class or an level-equivalent class of the class **ExceptionType2** (in the inheritance hierarchy tree)

```
class MultipleCatch1 {
    public static void main(String args[])
    {
        try {
            String num = args[0];
            int numValue = Integer.parseInt(num);
            System.out.println("Dien tich hv la: "
                               + numValue * numValue);
        } catch (Exception e1) {
            System.out.println("Hay nhap canh cua hv!");
        } catch (NumberFormatException e2) {
            System.out.println("Not a number!");
        }
    }
}
```

 D:\exception java.lang.NumberFormatException has already been caught

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- **ExceptionType1** must be a derived class or an level-equivalent class of the class **ExceptionType2** (in the inheritance hierarchy tree)

```
class MultipleCatch1 {
    public static void main(String args[])
    {
        try {
            String num = args[0];
            int numValue = Integer.parseInt(num);
            System.out.println("Dien tich hv la: "
                               + numValue * numValue);
        } catch (ArrayIndexOutOfBoundsException e1) {
            System.out.println("Hay nhap canh cua hv!");
        } catch (NumberFormatException e2) {
            System.out.println("Hay nhap 1 so!");
        }
    }
}
```

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```
class MultiCatch2 {
    public static void main( String args[]) {
        try {
            // format a number
            // read a file
            // something else...
        }
        catch (IOException e) {
            System.out.println("I/O error "+e.getMessage());
        }
        catch (NumberFormatException e) {
            System.out.println("Bad data "+e.getMessage());
        }
        catch (Throwable e) { // catch all
            System.out.println("error: " + e.getMessage());
        }
    }
}
```

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```

...
public void openFile(){
    try {
        // constructor may throw FileNotFoundException
        FileReader reader = new FileReader("someFile");
        int i=0;
        while(i != -1) {
            //reader.read() may throw IOException
            i = reader.read();
            System.out.println((char) i );
        }
        reader.close();
        System.out.println("--- File End ---");
    } catch (FileNotFoundException e) {
        //do something clever with the exception
    } catch (IOException e) {
        //do something clever with the exception
    }
}
...

```

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2.3.5. finally block

- Ensure that every necessary tasks are done when an exception occurs
 - Closing file, closing socket, connection
 - Releasing resource (if neccessary)...
- Must be done even there is an exception occurring or not.

```

graph LR
    try[try block] -- No exception --> finally1[finally]
    try -- Exception --> catch[catch block]
    catch --> finally2[finally]

```

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The syntax try ... catch ... finally

```

try {
    // May cause exceptions
}
catch(ExceptionType e) {
    // Handle exceptions
}
finally {
    /* Necessary tasks for all cases:
    exception is raised or not */
}

```

□ If there is a block try, there must be a block catch or a block finally or both

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```

class StrExceptionDemo {
    static String str;
    public static void main(String s[]) {
        try {
            System.out.println("Before exception");
            staticLengthmethod();
            System.out.println("After exception");
        }
        catch(NullPointerException ne) {
            System.out.println("There is an error");
        }
        finally {
            System.out.println("In finally");
        }
    }

    static void staticLengthmethod() {
        System.out.println(str.length());
    }
}

```

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```

public void openFile(){
    try {
        // constructor may throw FileNotFoundException
        FileReader reader = new FileReader("someFile");
        int i=0;
        while(i != -1) {
            //reader.read() may throw IOException
            i = reader.read();
            System.out.println((char) i );
        }
    } catch (FileNotFoundException e) {
        //do something clever with the exception
    } catch (IOException e) {
        //do something clever with the exception
    } finally {
        reader.close();
        System.out.println("--- File End ---");
    }
}

```

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Outline

1. Exceptions
2. Catching and handling exceptions
- ➔ 3. Exception delegation
4. User-defined exceptions

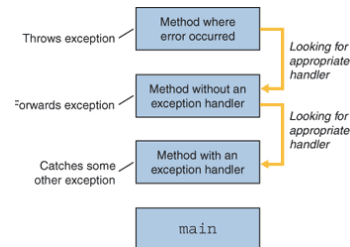
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Two ways to deal with exceptions

- Handle immediately
 - Using the block try ... catch (finally if necessary).
- Delegating to its caller:

- If we don't want to handle immediately
- Using throw and throws



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3.1. Exception delegation

- A method can delegate exceptions to its caller:
 - Using **throws** at the method definition to tell its caller of ExceptionType that it might cause an exception ExceptionType
 - Using **throw** anExceptionObject in the body of function in order to throw an exception when necessary
- For example


```

public void myMethod(int param) throws Exception{
    if (param < 10) {
        throw new Exception("Too low!");
    }
    //Blah, Blah, Blah...
}

```

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3.1. Exception delegation (2)

- If a method has some code that throws an exception, its declaration must declare a “throw” of that exception or the parent class of that exception

```
public void myMethod(int param) {
    if (param < 10) {
        throw new Exception("Too low!");
    }
    //Blah, Blah, Blah...
}
```

→ unreported exception java.lang.Exception; must be caught or declared to be thrown

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3.1. Exception delegation (3)

- A method without exception declaration will throw RuntimeException because this exception is delegated to JVM

- Example

```
class Test {
    public void myMethod(int param) {
        if (param < 10) {
            throw new RuntimeException("Too low!");
        }
        //Blah, Blah, Blah...
    }
}
```

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3.1. Exception delegation (3)

- At the caller of the method that has exception delegation (except RuntimeException):
 - Or the caller method must delegate to its caller
 - Or the caller method must catch the delegated exception (or its parent class) and handle immediately by try... catch (finally if necessary)

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```
public class DelegateExceptionDemo {
    public static void main(String args[]){
        int num = calculate(9,3);
        System.out.println("Lan 1: " + num);
        num = calculate(9,0);
        System.out.println("Lan 2: " + num);
    }
    static int calculate(int no, int nol)
        throws ArithmeticException {
        if (nol == 0)
            throw new
                ArithmeticException("Cannot devide by 0!");
        int num = no / nol;
        return num;
    }
}
```

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```

public class DelegateExceptionDemo {
    public static void main(String args[]){
        int num = calculate(9,3);
        System.out.println("Lan 1: " + num);
        num = calculate(9,0);
        System.out.println("Lan 2: " + num);
    }
    static int calculate(int no, int no1)
        throws Exception {
        if (no1 == 0)
            throw new
                ArithmeticException("Cannot divide by 0!");
        int num = no / no1;
        return num;
    }
}

```

G:\Java Example\DelegateExceptionDemo.java:3: unreported exception java.lang.Exception;
must be caught or declared to be thrown
int num = calculate(9,3);
^

G:\Java Example\DelegateExceptionDemo.java:5: unreported exception java.lang.Exception;
must be caught or declared to be thrown
num = calculate(9,0);

Compile

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```

public class DelegateExceptionDemo {
    public static void main(String args[]){
        try {
            int num = calculate(9,3);
            System.out.println("Lan 1: " + num);
            num = calculate(9,0);
            System.out.println("Lan 2: " + num);
        } catch(Exception e) {
            System.out.println(e.getMessage());
        }
    }
    static int calculate(int no, int no1)
        throws Exception {
        if (no1 == 0)
            throw new
                ArithmeticException("Cannot divide by 0!");
        int num = no / no1;
        return num;
    }
}

```

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3.1. Exception delegation (4)

- A method can delegate more than 1 exception

```

public void myMethod(int age, String name)
    throws ArithmeticException, NullPointerException{
    if (age < 18) {
        throw new ArithmeticException
            ("Age must be at least 18");
    }
    if (name == null) {
        throw new NullPointerException
            ("Name must be provided");
    }
    //Blah, Blah, Blah...
}

```

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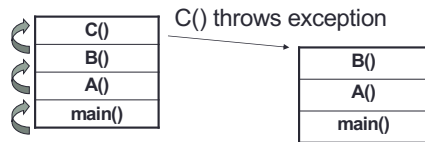
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3.2. Exception propagation

- Scenario:
 - Assuming that in main() method A() is called, B() is called in A(), C() is called in B(). Then a stack of method is created.
 - Assuming that in C() there is an exception occurring.

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3.2. Exception Propagation (2)



If C() has an error and throws an exception but in C() that exception is not handled, hence there is only one place that handles the exception, that place is where C() is called, it is the method B().

If in B() there is no exception handling, then the exception must be handled in A() ... This is called Exception Propagation

If in main(), the exception thrown from C() can not be handled, the program will be interrupted.

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3.3. Inheritance and exception delegation

- When overriding a method of a parent class, methods in its child classes can not throw any new exception

→ Overridden method in a child class can only throw a set of exceptions that are/similar to/ a subset of exceptions thrown from the parent class.

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3.3. Inheritance and exception delegation(2)

```
class Disk {
    void readFile() throws EOFException {}
}
class FloppyDisk extends Disk {
    void readFile() throws IOException {} // ERROR!
}
```



```
class Disk {
    void readFile() throws IOException {}
}
class FloppyDisk extends Disk {
    void readFile() throws EOFException {} //OK
}
```

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3.4. Advantages of exception delegation

- Easy to use
 - Making programs easier to read and more reliable
 - Easy to send control to the places that can handle exceptions
 - Can throw many types of exceptions
- Separating exception handling from the main code
- Do not miss any exception (throw automatically)
- Grouping and categorizing exceptions
- Making program easier to read and more reliable

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Outline

1. Exceptions
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3. Exception delegation
- ➔ 4. User-defined exceptions

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4. User-defined exception

- Exceptions provided can not controll all the errors → Need to have exceptions that are defined by users.
- Inheriting from the class **Exception** or one of its child classes
- Having all the methods of the class **Throwable**

```
public class MyException extends Exception {
    public MyException(String msg) {
        super(msg);
    }
    public MyException(String msg, Throwable cause){
        super(msg, cause);
    }
}
```

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Using self-defined exceptions

Declaring that an exception might be thrown

```
public class FileExample
{
    public void copyFile(String fName1,String fName2)
    throws MyException
    {
        if (fName1.equals(fName2))
            throw new MyException("File trung ten");
        // Copy file
        System.out.println("Copy completed");
    }
}
```

Throwing an exception

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Using self-defined exceptions

- Catching and handling exceptions

```
public class Test {
    public static void main(String[] args) {
        FileExample obj = new FileExample();
        try {
            String a = args[0];
            String b = args[1];
            obj.copyFile(a,b);
        } catch (MyException e1) {
            System.out.println(e1.getMessage());
        }
        catch(Exception e2) {
            System.out.println(e2.toString());
        }
    }
}
```

```
C:\>java Test a1.txt a1.txt
File trung ten
C:\>java Test
java.lang.ArrayIndexOutOfBoundsException: 0
```

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Quiz

Modify the following source code so that `copyFile()` method will throw 2 exceptions:

- `MyException` if the 2 file names are equal, and
- `IOException` if there is any error during the copy file process

```
public class FileExample {
    public void copyFile(String fName1,String fName2)
        throws MyException{
        if (fName1.equals(fName2))
            throw new MyException("Duplicate file name");

        // Copy file

        System.out.println("Copy completed");
    }
}
```

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Conclusion (3)

- Types of exception handling:
 - Fix errors and call again the method that caused these errors
 - Fix errors and continue running the method
 - Handling differently instead of ignoring the result
 - Exit the program

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