6. Java Errors and Exceptions

Errors, runtime-exceptions, checked-exceptions, exception handling, special case: resources

Errors and Exceptions in Java

Errors and exceptions interrupt the normal execution of the program abruptly and represent an *unplanned event*.

Exceptions are bad, or not?

- Java allows to catch such events and deal with it (as opposed to crashing the entire program)
- Unhandled errors and exceptions are passed up through the call stack.

Errors


This glass is broken for good

Errors happen in the virtual machine of Java and are *not repairable*.

Examples

- No more memory available
- Too high call stack (→ recursion)
- Missing libraries
- Bug in the virtual machine
- Hardware error

Exceptions

Exceptions are triggered by the virtual machine or the program itself and can typically be handled in order to *re-establish the normal situation*


Clean-up and pour in a new glass

Examples

- De-reference `null`
- Division by zero
- Read/write errors (on files)
- Errors in business logic

Exception Types

Runtime Exceptions

- Can happen anywhere
- *Can* be handled
- Cause: bug in the code

Checked Exceptions

- Must be declared
- *Must* be handled
- Cause: Unlikely but not impossible event

Example of a Runtime Exception

```java
import java.util.Scanner;
class ReadTest {
    public static void main(String[] args){
        int i = readInt("Number");
    }
    private static int readInt(String prompt){
        System.out.print(prompt + ": ");
        Scanner input = new Scanner(System.in);
        return input.nextInt();
    }
}
```

Input: `Number: asdf`

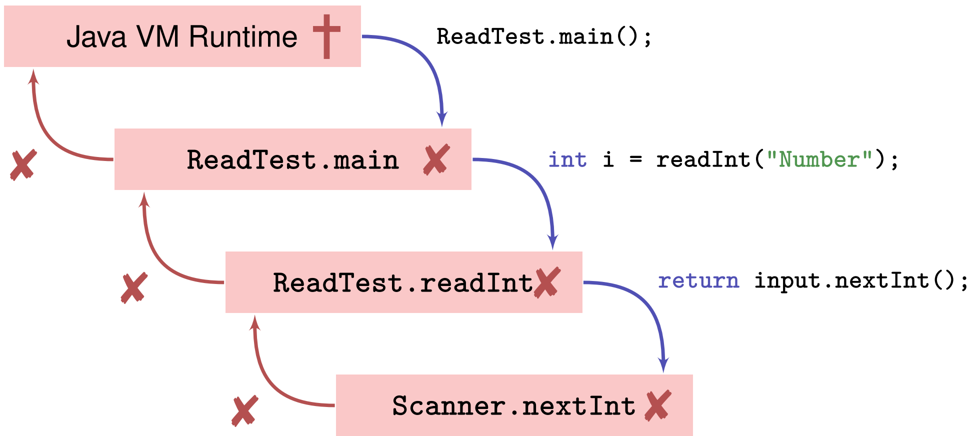
Unhandled Errors and Exceptions

The program crashes and leaves behind a *stack trace*. In there, we can see the where the program got interrupted.

```
Exception in thread "main" java.util.InputMismatchException
            [...]
        at java.util.Scanner.nextInt(Scanner.java:2076)
        at ReadTest.readInt(ReadTest.java:9)
        at ReadTest.main(ReadTest.java:4)
```

⇒ Forensic investigation based on this information.

Exception gets Propagated through Call Stack



Unstanding Stack Traces

An unsuited input ...

Output:

```
Exception in thread "main" java.util.InputMismatchException
        at java.util.Scanner.throwFor(Scanner.java:864)
        at java.util.Scanner.next(Scanner.java:1485)
        at java.util.Scanner.nextInt(Scanner.java:2117)
        at java.util.Scanner.nextInt(Scanner.java:2076)
        at ReadTest.readInt(ReadTest.java:9)
        at ReadTest.main(ReadTest.java:4)
```

... in method `readInt` *on line 9 ...*

... called by method `main` *on line 4.*

Unstanding Stack Traces

```
1  import java.util.Scanner;
2  class ReadTest {
3      public static void main(String[] args){
4          int i = readInt("Number");
5      }
6      private static int readInt(String prompt){
7          System.out.print(prompt + ": ");
8          Scanner input = new Scanner(System.in);
9          return input.nextInt();
10     }
11 }
```

```
at ReadTest.readInt(ReadTest.java:9)
at ReadTest.main(ReadTest.java:4)
```


Runtime Exception: Bug in the Code?!

Where is the bug?

```
private static int readInt(String prompt){
    System.out.print(prompt + ": ");
    Scanner input = new Scanner(System.in);
    return input.nextInt();
}
```

Not guaranteed that the next input is an `int`

⇒ The scanner class provides a test for this

Runtime Exception: Bug Fix!

Check first!

```
private static int readInt(String prompt){
    System.out.print(prompt + ": ");
    Scanner input = new Scanner(System.in);
    if (input.hasNextInt()){
        return input.nextInt();
    } else {
        return 0; // or do something else ...?!
    }
}
```

First Finding: often no Exceptional Situation

Often, those “exceptional” cases aren’t that unusual, but pretty foreseeable. In those cases *no* exceptions should be used!

Kids are tipping over cups. You get used to it.

Examples

- Wrong credentials when logging in
- Empty required fields in forms
- Unavailable internet resources
- Timeouts

Second Finding: Avoid Exceptions

Problem solved.

Instead of letting a runtime exception happen, *actively prevent* such a situation to arise.

Examples

- Check user inputs early
- Use optional types
- Predict timeout situations
- Plan B for unavailable resources

Exception Types

Runtime Exceptions

- Can happen anywhere
- *Can* be handled
- Cause: bug in the code

Checked Exceptions

- Must be declared
- *Must* be handled
- Cause: Unlikely but not impossible event

Example of a Checked Exception

```
private static String[] readFile(String filename){
    FileReader fr = new FileReader(filename);
    BufferedReader bufr = new BufferedReader(fr);
    ...
    line = bufr.readLine();
    ...
}
```

Compiler Error:

```
./Root/Main.java:9: error: unreported exception FileNotFoundException; must be caught or declared to be
    FileReader fr = new FileReader(filename);
                    ^
./Root/Main.java:11: error: unreported exception IOException; must be caught or declared to be thrown
    String line = bufr.readLine();
                               ^
2 errors
```

Quick Look into Javadoc

readLine

```
public String readLine()
                throws IOException
```

Reads a line of text. A line is considered to be terminated by any one of a line feed ('\n'), a carriage return ('\r'), or a carriage return followed immediately by a linefeed.

Returns:

`A String containing the contents of the line, not including any line-termination characters, or null if the end of the stream has been reached`

Throws:

`IOException - If an I/O error occurs`

See Also:

`Files.readAllLines(java.nio.file.Path, java.nio.charset.Charset)`

Why use Checked Exceptions?

The following situations justify checked exception:

- Fault is *unprobable but not impossibe* – and can be fixed by taking suitable measures at runtime.

The caller of a method with a declared checked exception is forced to deal with it – catch it or pass it up.

Handling Exceptions

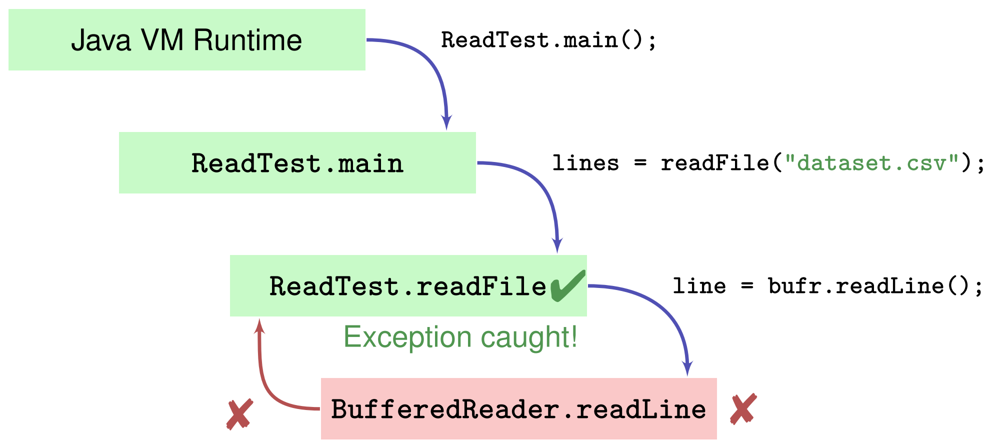
```
private static String[] readFile(String filename){
    try{
        FileReader fr = new FileReader(filename);
        BufferedReader bufr = new BufferedReader(fr);
        ...
        line = bufr.readLine();
        ...
    } catch (IOException e){
        // do some recovery handling
    } finally {
        // close resources
    }
}
```

Protected scope

Measures to re-establis the normal situation

Gets executed in any case, at the end, always!

Handling Exceptions: Stop Propagation!



Finally: Closing Resources

In Java, *resources* must be closed after use at all costs. Otherwise, memory won't get freed.

Resources:

- Files
- Data streams
- UI elements
- ...

Try-With-Resources Statement

Specific syntax to close resources *automatically*:

```
private static String[] readFile(String filename){
    try ( FileReader fr = new FileReader(filename);
      BufferedReader bufr = new BufferedReader(fr)) {
        ...
        line = bufr.readLine();
        ...
    } catch (IOException e){
        // do some recovery handling
    }
}
```

Resources get opened here

Resources get closed automatically here

7. Functional Concepts in Java

Functional programming, lambda expressions, streams, pipelines

Functional vs. Imperative Programming

Imperative concepts

- Executing statements
- State (e.g. Fields)
- Mutable data types
- Focus on data structures
- Focus on "how"

Functional Concepts

- Evaluating expressions
- Stateless
- Immutable data types
- Focus on streams
- Focus on "what"

Example: Reading of Files - Imperative

```
try (BufferedReader br=new BufferedReader(new FileReader("data.csv"))){
    LinkedList<Measurement> result = new LinkedList<>();
    br.readLine();
    String line;
    while ((line = br.readLine()) != null){
        Measurement m = new Measurement(line);
        result.add(m);
    }
    return result;
}
```


Example: Readong of Files - Functional

```
try (Stream<String> stream = Files.lines(Paths.get("data.csv"))) {


    return stream.skip(1).map(Measurement::new).collect(toList());



}
```


Streams

In Java, *Streams* are the basis for functional programming. Sources of streams:

- Files
- Arrays
- Data structures
- ...

Example

```
Stream<String> stream = Files.lines (...))
```


Operations on Streams: Map

Map: Applying functions on individual elements of the stream

- Mathematical computations
- Creation of new objects based on existing elements.
- ...

Example

```
map(Measurement::new)
```

Operations on Streams: Reduce

Reduce: Aggregation of individual elements of a stream to one single value.

- Statistical aggregation
- Put elements in a data structure
- ...

Example

```
collect(toList())
```


Example: Search for Data - Imparative

```
List<Measurement> data = readCsvData();
Coordinate ref = readCoordinate();

for (Measurement m : data){
    if (m.position.near(ref)){
        System.out.println(m.originalLine);
    }
}
```


Example: Search for Data - Functional

```
List<Measurement> data = readCsvData();
Coordinate ref = readCoordinate();

data.stream()
        .filter(m -> ref.near(m.position))
        .forEach(System.out::println);
```


Operations on Streams: Filter

Filter: Filter individual elements of a stream.

- Remove illegal values
- Select values based on inquiries
- ...

Example

```
filter(m -> ref.near(m.position))
```

Operations on Streams: Side Effects

Sideeffects: The non-functional aspect: Execution on arbitrary operations based on individual elements.

- Input/Output
- Update data structures
- ...

Example

```
forEach(System.out::println)
```


Functionality as Parameter

Operations on streams have *functionality* (code) as parameter, instead of *data*

Possibility to pass functionality (instead of data)

- code snippets
- References on methods
- References to constructors

How can we do this?

Lambda Expressions

Lambda expressions are basically methods without names.

Normal method

```
double discriminant(double a, double b, double c){
    return b*b - 4*a*c;
}
```

Equivalent lambda expression

```
(double a, double b, double c) -> {
    return b*b - 4*a*c;
}
```


Lambda Expressions

Lambda expression

```
(double a, double b, double c) -> {
    return b*b - 4*a*c;
}
```

Without explicit type declaration of the parameters

```
(a, b, c) -> {
    return b*b - 4*a*c;
}
```

With a single expression instead of a block

```
(a, b, c) -> b*b - 4*a*c
```

Lambda Expression in the Example

Example

```
filter (m -> ref.near(m.position))
```

- The method `filter` expects a method as parameter that takes a `Measurement` as parameter and returns a `boolean`.
- `m` is a parameter of type `Measurement` ✓
- `ref.near(m.position)` is a single `boolean` expression ✓
- The variable `ref` from the defining context is accessible, if it is *effectively* constant (`final`).

References on Methods

To *call* a method on an object, we write:

`object.method()`

To specify a *reference* to a method on an object, we write:

`object::methode`

References on Static Methods

To *call* a static method, we write:

`Clazz.method()`

To specify a *reference* to a static method, we write:

`Clazz::method`

Reference to a Method in the Example

Example

```
forEach(System.out::println)
```

- The method `forEach` expects a method, which doesn't return anything and takes an argument of type `Measurement`.
- The method `println` on object `out` satisfies those properties ✓

References to Constructors

To *call* a constructor of a class, we write:

```
new Clazz()
```

To specify a *reference* to a constructor of a class, we write:

```
Clazz::new
```


References to a Constructor in the Example

Example

```
map(Measurement::new)
```

- The method `map` expects a method that returns an object of a certain data types (it doesn't matter which) and an argument of type `String`.
- The constructor of the class `Measurement` satisfies this property ✓

Advantages and Disadvantages of Functional Programming

Advantages	Disadvantages
Less error-prone Easier to maintain Allows for elegant programming constructs Independent on specific architecture	Learn another language concept Details on the execution are unknown Super-imposed on an imperative language