Computer System Design & Application

计算机系统设计与应用A

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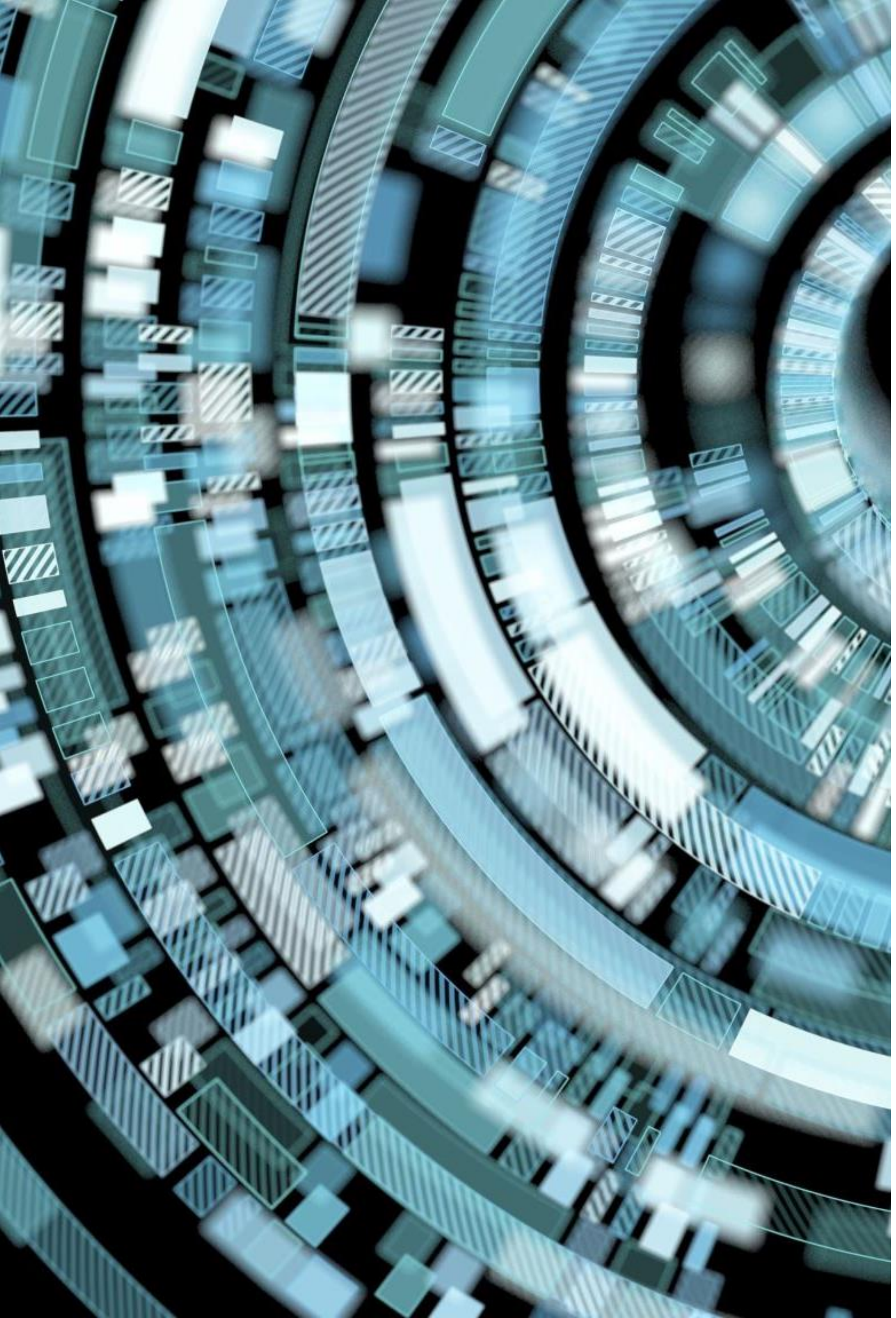


Lecture 6

- Persistence and Serialization
- Working with Files
- Exception Handling

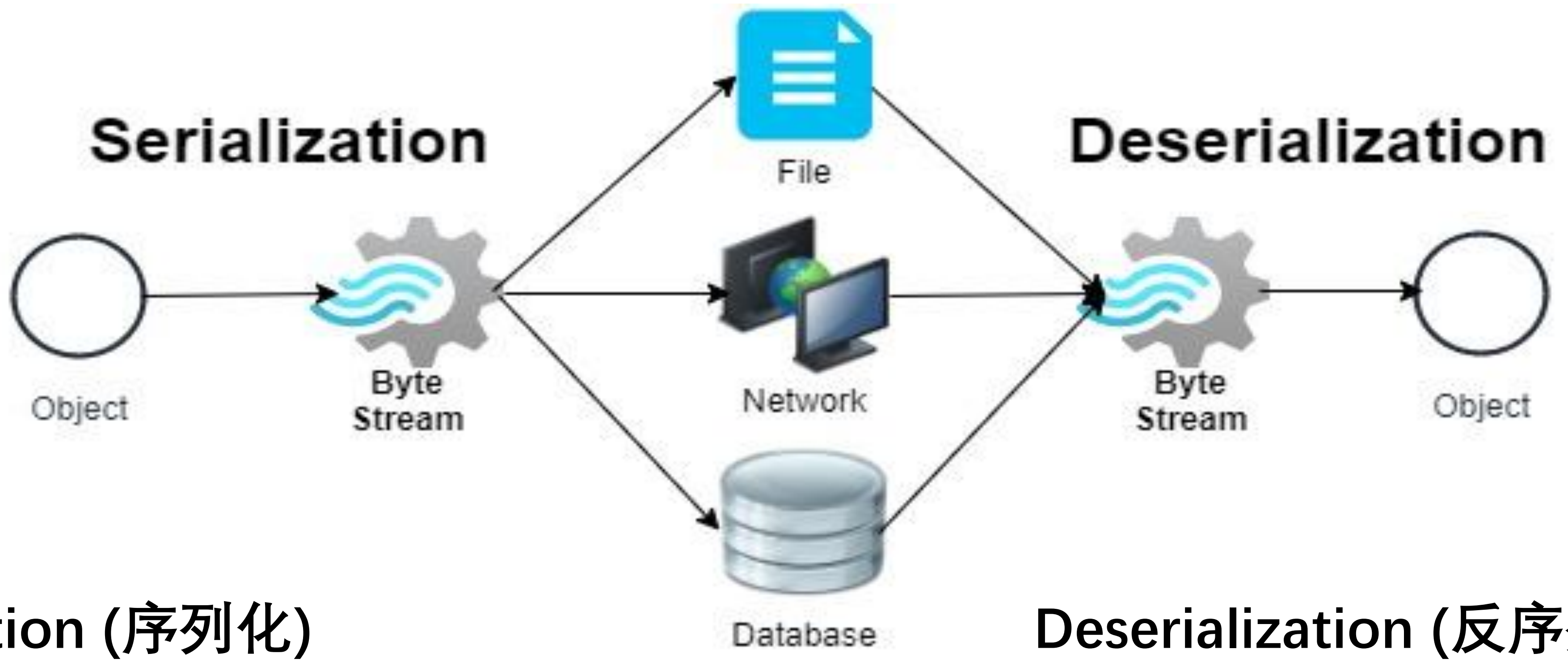
Data Persistence (数据持久化)

- Objects created in Java programs live in memory；they are removed by the garbage collector once they are not used anymore
- What if we want to persist the objects?

Data survives after the process that created it has ended.

Reuse the data without having to executing the program all over again to reach that state.

Data persistence
Store it on a disk, send it over the network



Serialization (序列化)
Converting the state of an object into a byte stream

Deserialization (反序列化)
Using the byte stream to recreate the object in the same state

The `Serializable` Interface

- Classes need to implement the `serializable` interface for their instances to be serialized or deserialized

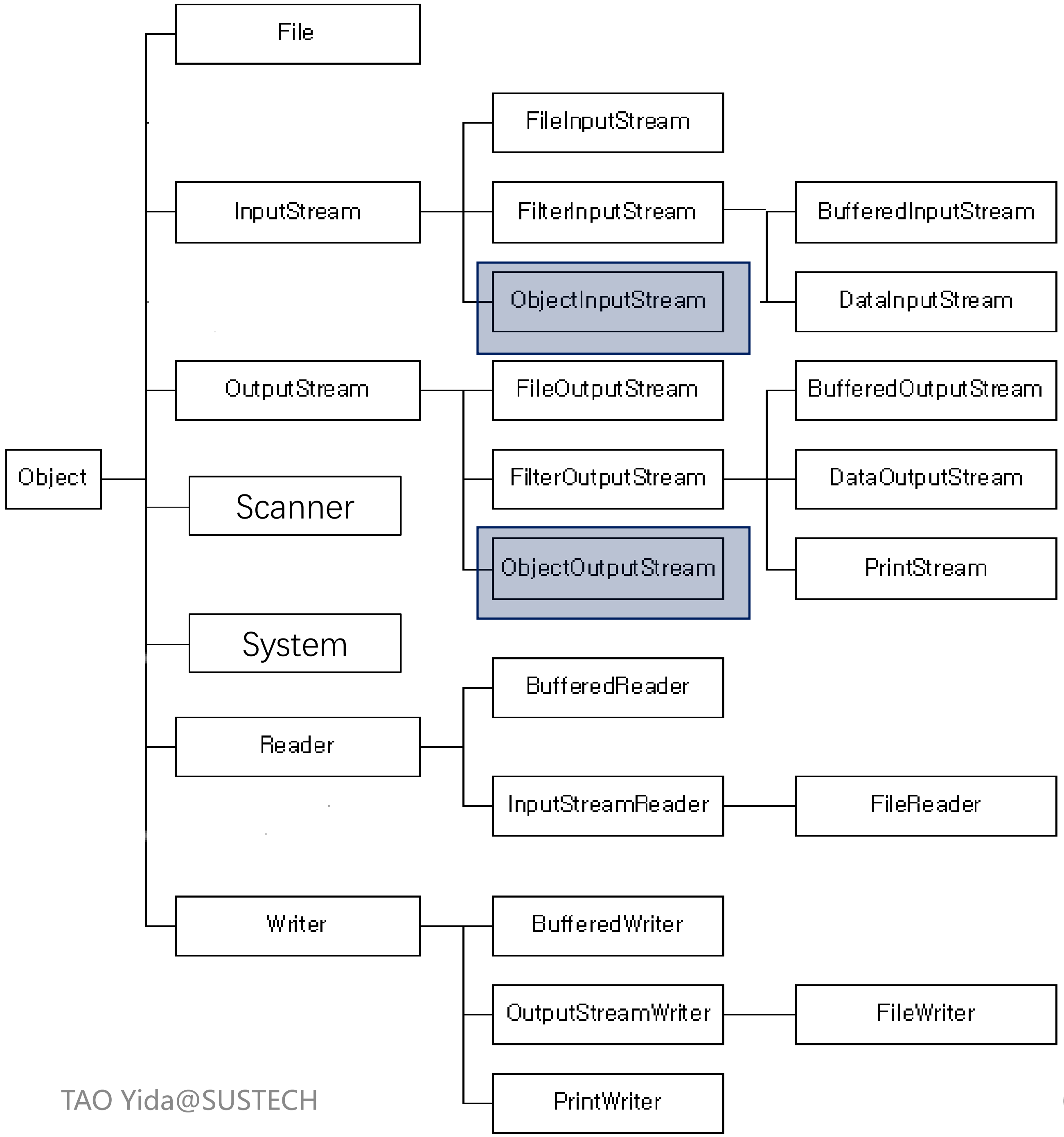
- The `serializable` interface is called a marker interface or tagging interface (like putting a tag on the class, so the compiler and JVM, when seeing the tag, knows that the object of the class could be serialized)
    - The `serializable` interface is an empty interface, without any method or field
    - Classes implementing `serializable` do not have to implement any methods

```java
class Student implements Serializable {
    String name;
    String dept;
    int age;

    public String getName() {
        return name;
    }

    public String getDept() {
        return dept;
    }

    public int getAge() {
        return age;
    }

    public Student(String name, String dept, int age) {
        this.name = name;
        this.dept = dept;
        this.age = age;
    }
}
```

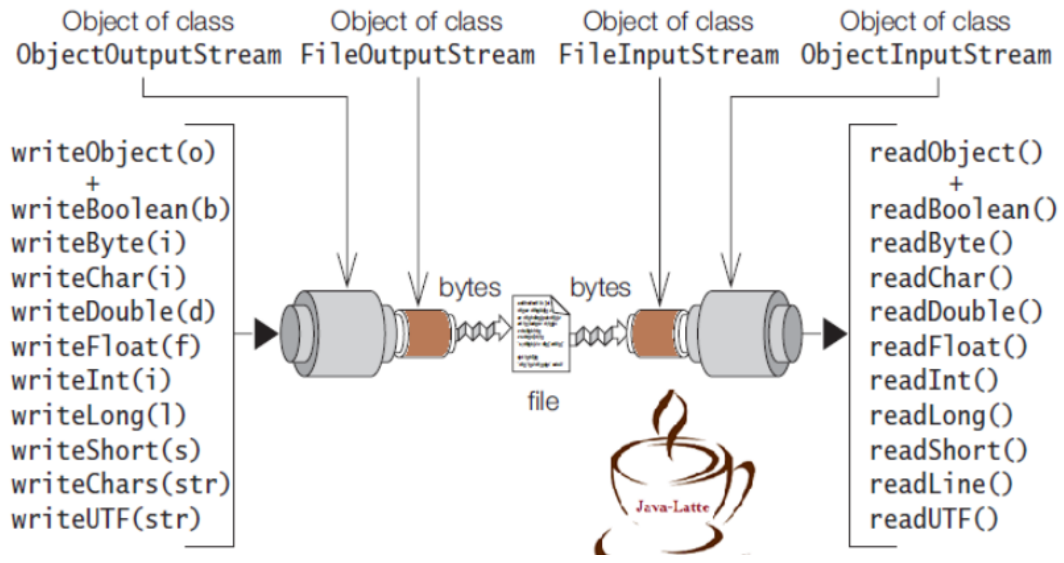
Using Object Input/Output Streams

`ObjectOutputStream` writes primitive data types and Java objects to an `OutputStream`, using `writeXXX`

`ObjectIutputStream` deserializes primitive data and objects previously written using an `ObjectOutputStream`. Using `readXXX`



Example



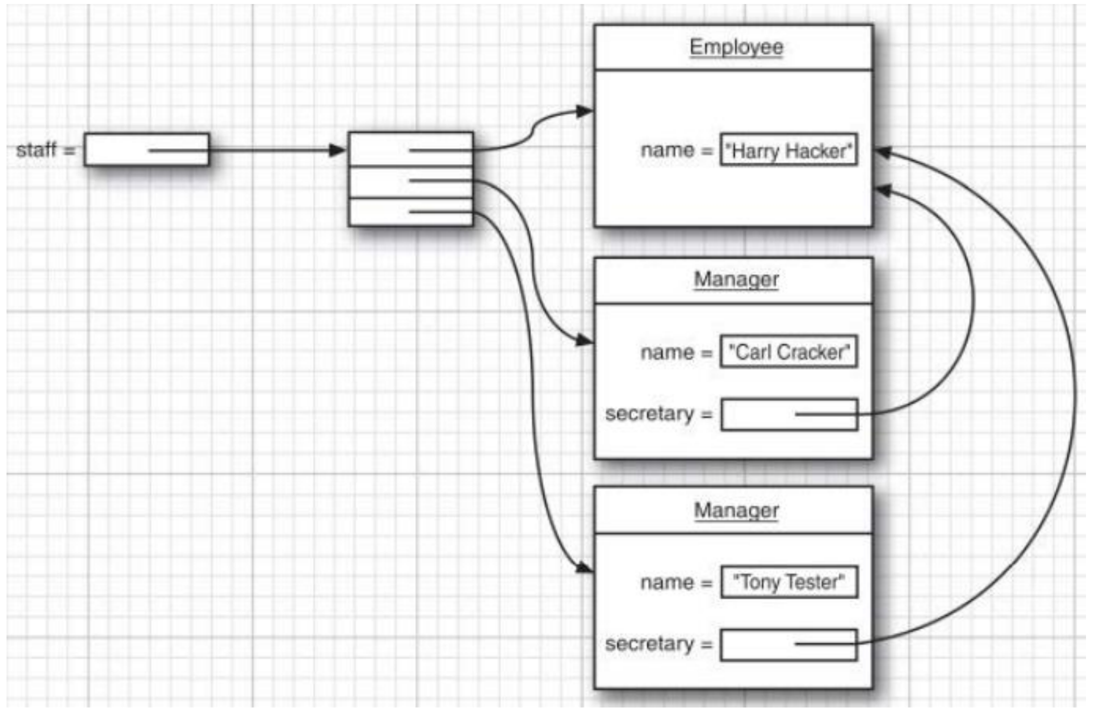
http://java-latte.blogspot.com/2013/11/serialization-in-java.html

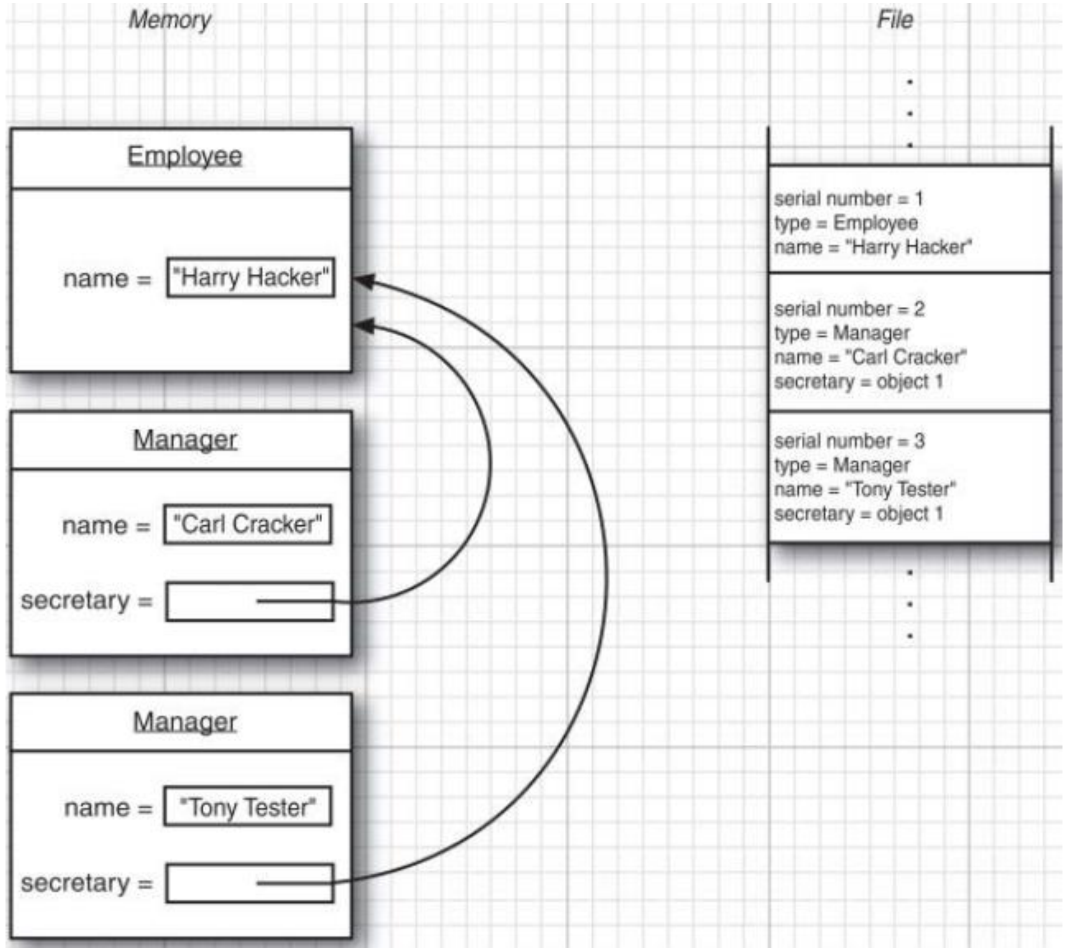
```
Student student = new Student("Alice", "CS", 20);

// Setup where to store the byte stream
FileOutputStream fos = new FileOutputStream("student.ser");
ObjectOutputStream oos = new ObjectOutputStream(fos);

// serialization
oos.writeObject(student);

//Setup where to read the byte stream
FileInputStream fis = new FileInputStream("student.ser");
ObjectInputStream ois = new ObjectInputStream(fis);

// deserialization
Student student2 = (Student) ois.readObject(); // down-casting
object

System.out.println(student.getName() + " " +
student2.getName());
System.out.println(student.getDept() + " " + student2.getDept());
System.out.println(student.getAge() + " " + student2.getAge());

oos.close();
ois.close();
```

Default Serialization Mechanism

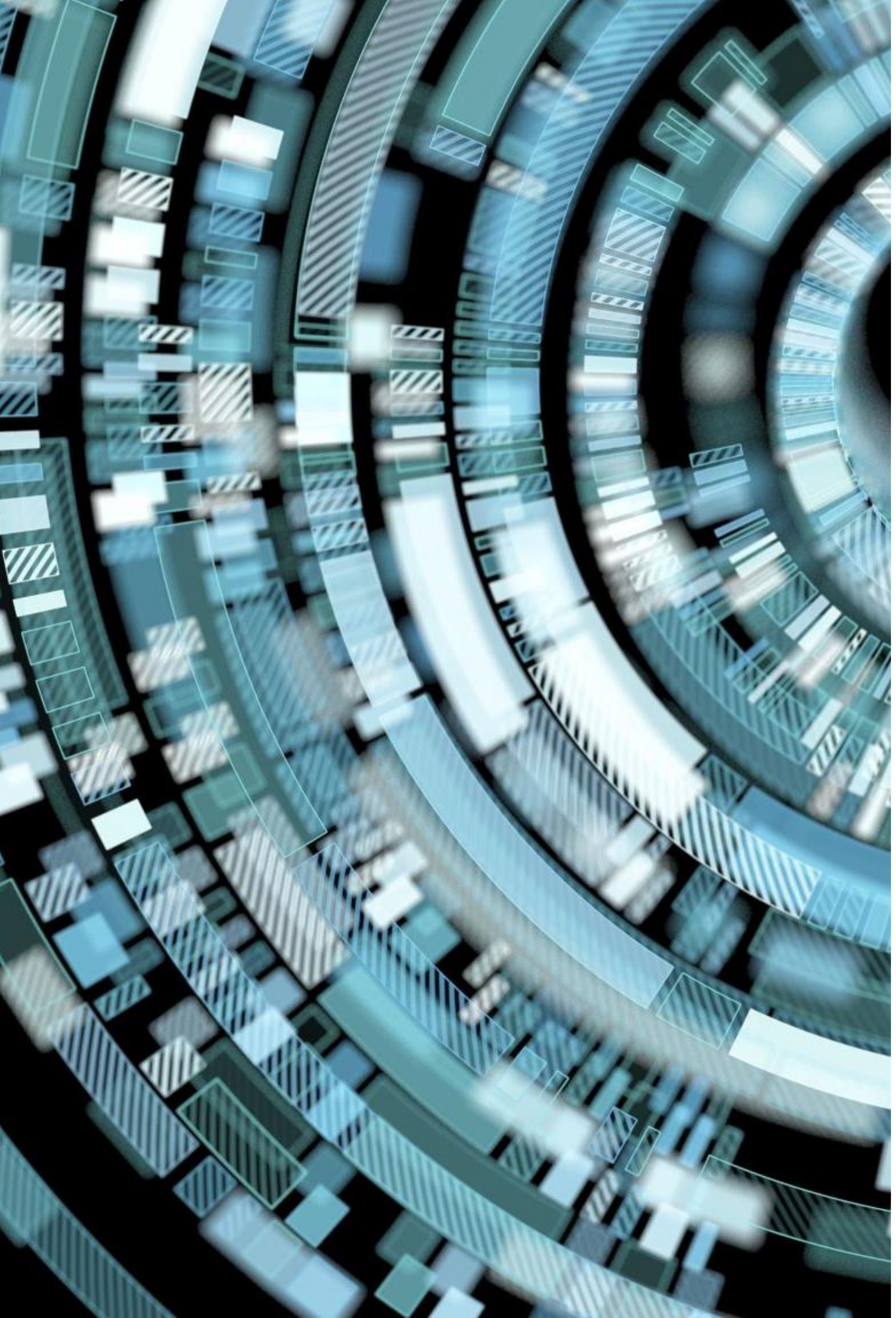
- An `ObjectOutputStream` looks at all the fields of the objects and save their contents.
- The serialized format contains the types and data fields of all objects.
- Each object is assigned a serial number.
- Repeated occurrences of the same object are stored as references to that serial number.

Example





Reference: Core Java Volume II, 2.4



Lecture 6

- Persistence and Serialization
- Working with Files
- Exception Handling

Working with Files

- We have learned how to read and write data from a file, yet there is more to file management than reading & writing

- The `Path` interface, `Paths` class, and `Files` class, introduced in Java 7 (`java.nio` package), are much more convenient than the File class dated back all the way to JDK 1.0

Path

```
import java.nio.file.Path;
import java.nio.file.Paths;
```

- A `Path` instance contains the information used to specify the location of a file or directory
- You can easily create a `Path` object by using one of the following `get` methods from the `Paths` helper class

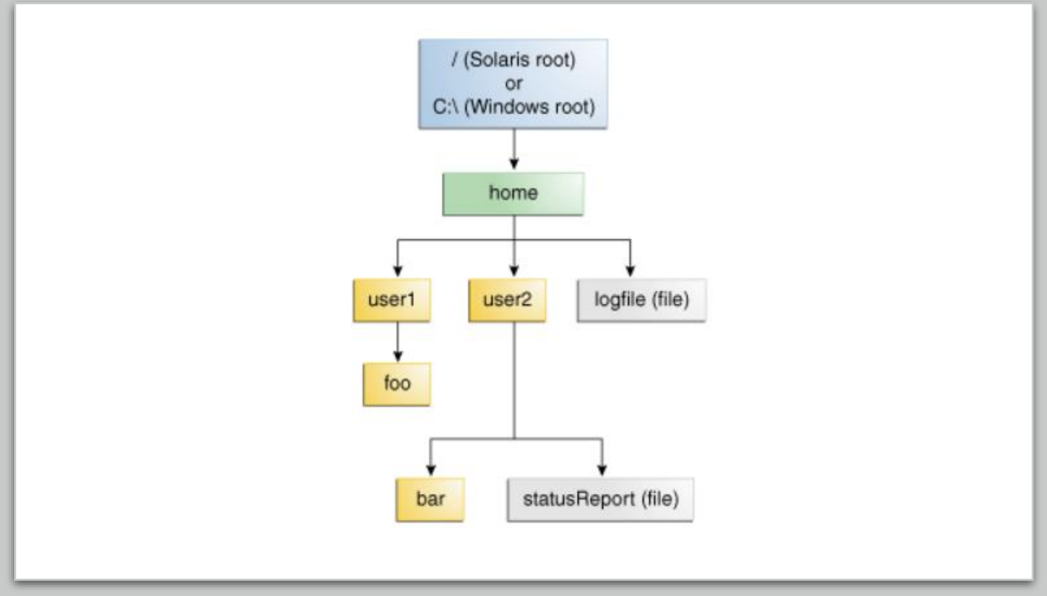
```
Path p1 = Paths.get("resources");
Path p2 = Paths.get(args[0]);
Path p3 = Paths.get(URI.create("file:///D:/CS209A/sample123.txt"));
```

https://docs.oracle.com/javase/tutorial/essential/io/pathOps.html

Path

- `Path` stores these name elements as a sequence.
  - The highest element in the directory structure would be located at index 0.
  - The lowest element in the directory structure would be located at index [n-1], where n is the number of name elements in the Path.
- A path that starts with root is absolute; otherwise, it is relative

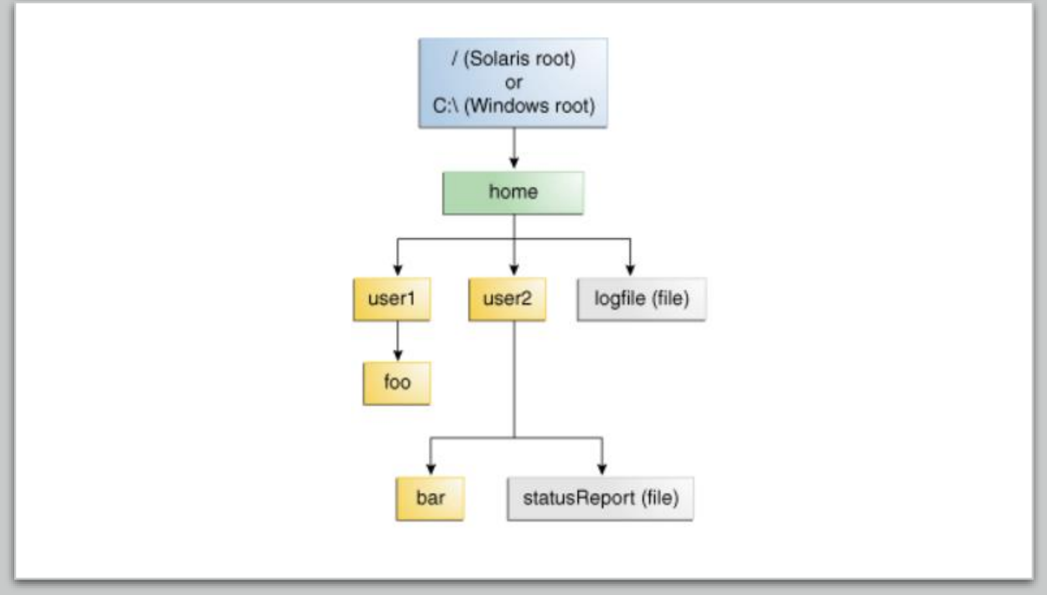
https://docs.oracle.com/javase/tutorial/essential/io/pathOps.html

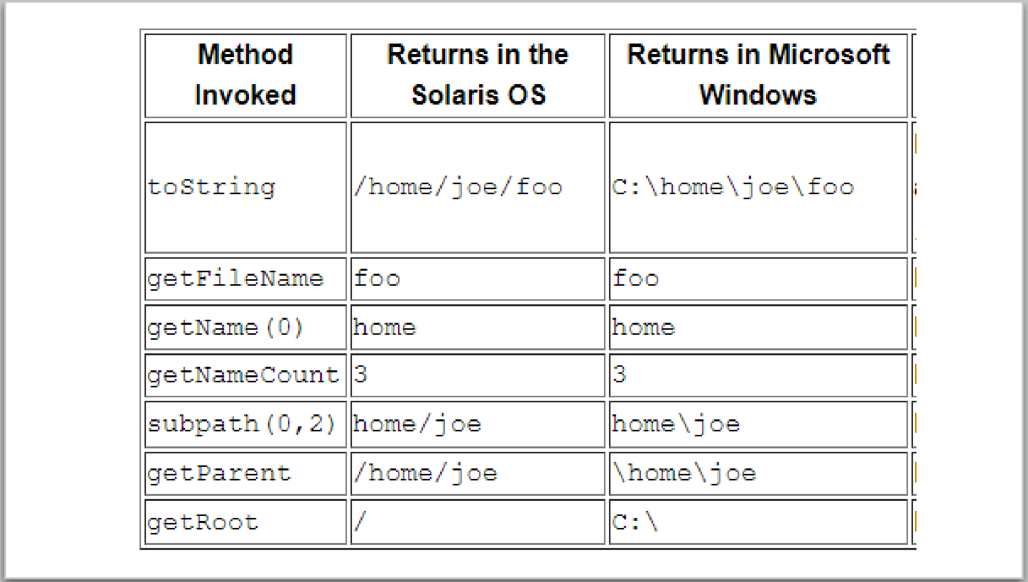


Path

```
// Microsoft Windows syntax
Path path = Paths.get("C:\\home\\joe\\foo");

// Solaris syntax
Path path = Paths.get("/home/joe/foo");

System.out.format("toString: %s%n", path.toString());
System.out.format("getFileName: %s%n", path.getFileName());
System.out.format("getName(0): %s%n", path.getName(0));
System.out.format("getNameCount: %d%n", path.getNameCount());
System.out.format("subpath(0,2): %s%n", path.subpath(0,2));
System.out.format("getParent: %s%n", path.getParent());
System.out.format("getRoot: %s%n", path.getRoot());
```

https://docs.oracle.com/javase/tutorial/essential/io/pathOps.html





Method Invoked	Returns in the Solaris OS	Returns in Microsoft Windows
toString	/home/joe/foo	C:\home\joe\foo
getFileName	foo	foo
getName(0)	home	home
getNameCount	3	3
subpath(0,2)	home/joe	home\joe
getParent	/home/joe	\home\joe
getRoot	/	C:\

Dot notations

- When working with relative paths, you may use two special notations inside the path string:
  - . (current directory)
  - .. (parent directory)

- You may use `normalize()` method to remove redundancies from a path

```
Path rp1 = Paths.get("C:\\Users\\admin\\CS209A_Lectures\\.");
Path rp2 = Paths.get("C:\\Users\\admin\\test\\..\\CS209A_Lectures");

System.out.format("rp1 normalize: %s%n", rp1.normalize());
System.out.format("rp2 normalize: %s%n", rp2.normalize());
```

Both normalizes to “C:\Users\admin\CS209A_Lectures”

Converting a Path

`toAbsolutePath()`

- Converts a path to an absolute path. If the passed-in path is already absolute, it returns the same Path object.
- The file does not need to exist for this method to work.

`toRealPath()`

- If the Path is relative, it returns an absolute path.
- If the Path contains any redundant elements, it returns a path with those elements removed.
- Throws an exception if the file does not exist or cannot be accessed.

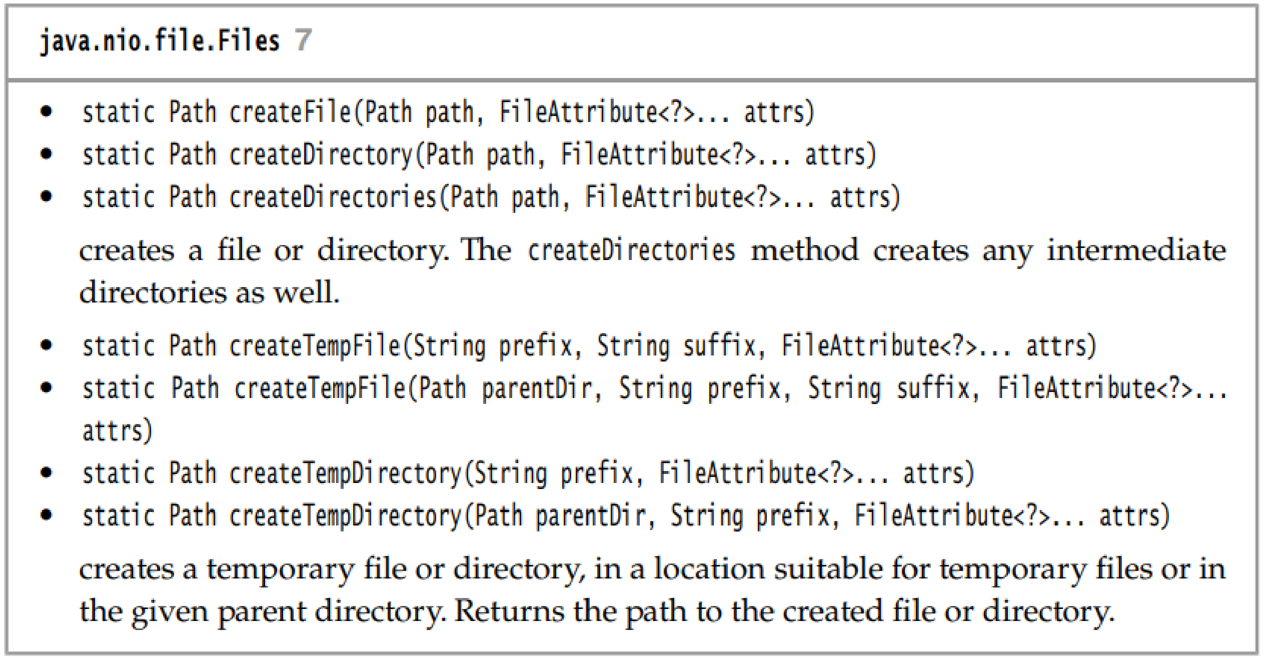
Converting a Path

```
Path cp = Paths.get("resources\\..\\resources\\math.txt");
// C:\Users\admin\CS209A_Lectures\resources\..\resources\math.txt
System.out.println(cp.toAbsolutePath());
// C:\Users\admin\CS209A_Lectures\resources\math.txt
System.out.println(cp.toRealPath());


Path cp2 = Paths.get("resources\\..\\resources\\notexist.txt");
// C:\Users\admin\CS209A_Lectures\resources\..\resources\notexist.txt
System.out.println(cp2.toAbsolutePath());
// Throws NoSuchFileException
System.out.println(cp2.toRealPath());
```

Files

This class, `java.nio.file.Files`, consists exclusively of static methods that operate on files, directories, or other types of files.

Creating Files and Directories



java.nio.file.Files 7

- `static Path createFile(Path path, FileAttribute<?>... attrs)`
- `static Path createDirectory(Path path, FileAttribute<?>... attrs)`
- `static Path createDirectories(Path path, FileAttribute<?>... attrs)`

  creates a file or directory. The `createDirectories` method creates any intermediate directories as well.

- `static Path createTempFile(String prefix, String suffix, FileAttribute<?>... attrs)`
- `static Path createTempFile(Path parentDir, String prefix, String suffix, FileAttribute<?>... attrs)`
- `static Path createTempDirectory(String prefix, FileAttribute<?>... attrs)`
- `static Path createTempDirectory(Path parentDir, String prefix, FileAttribute<?>... attrs)`

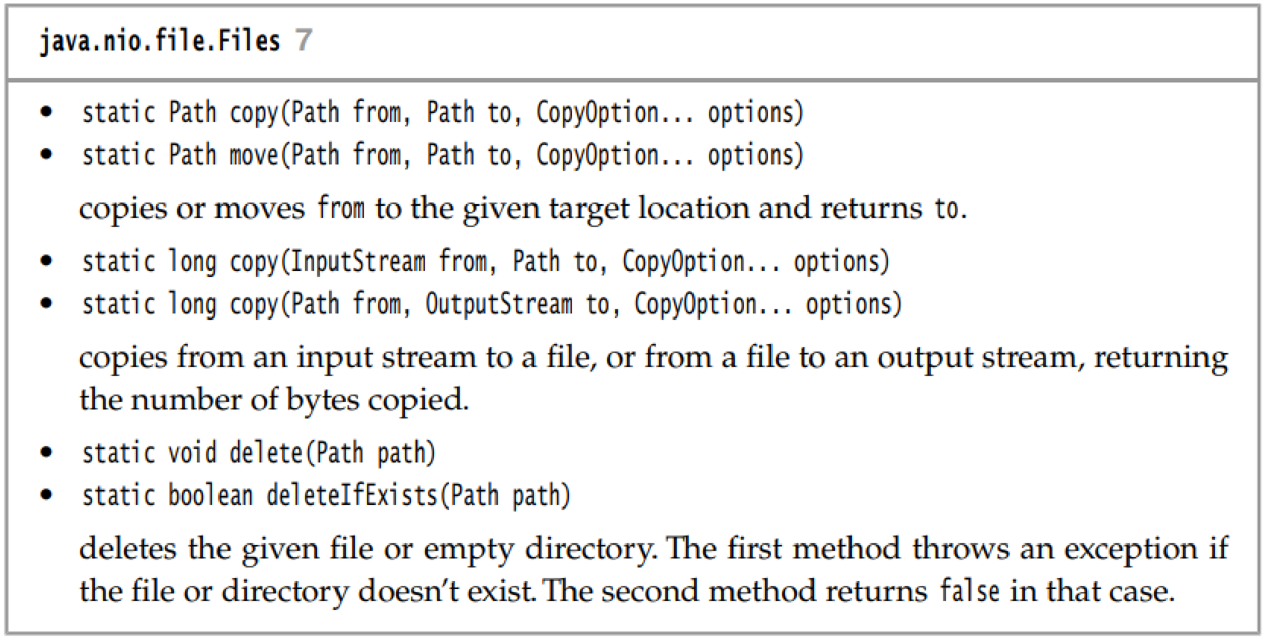
  creates a temporary file or directory, in a location suitable for temporary files or in the given parent directory. Returns the path to the created file or directory.

Core Java, Volume II, Chapter 2

Files

This class, `java.nio.file.Files`, consists exclusively of static methods that operate on files, directories, or other types of files.

Copying, Moving, and Deleting Files



`java.nio.file.Files` 7

- `static Path copy(Path from, Path to, CopyOption... options)`
- `static Path move(Path from, Path to, CopyOption... options)`

  copies or moves `from` to the given target location and returns `to`.

- `static long copy(InputStream from, Path to, CopyOption... options)`
- `static long copy(Path from, OutputStream to, CopyOption... options)`

  copies from an input stream to a file, or from a file to an output stream, returning the number of bytes copied.

- `static void delete(Path path)`
- `static boolean deleteIfExists(Path path)`

  deletes the given file or empty directory. The first method throws an exception if the file or directory doesn't exist. The second method returns `false` in that case.

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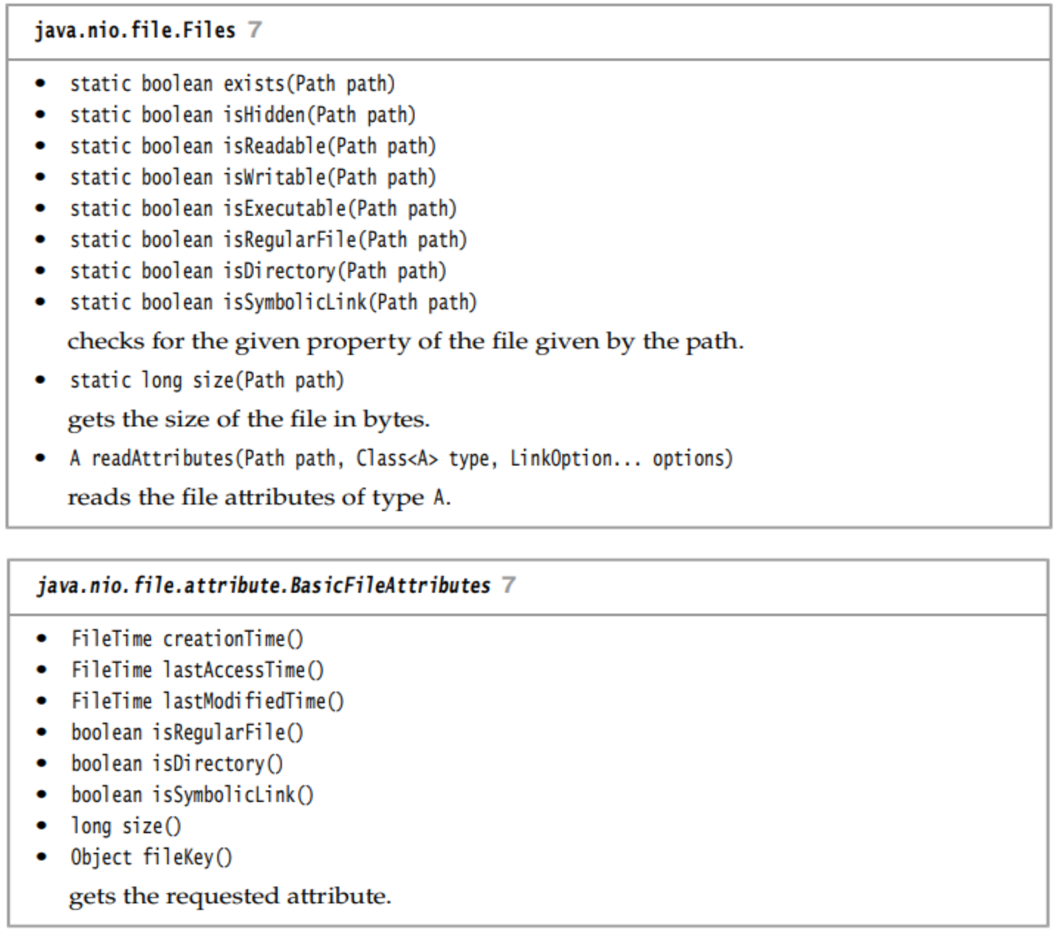
Files

This class, `java.nio.file.Files`, consists exclusively of static methods that operate on files, directories, or other types of files.

Getting File Information



java.nio.file.Files 7

- `static boolean exists(Path path)`
- `static boolean isHidden(Path path)`
- `static boolean isReadable(Path path)`
- `static boolean isWritable(Path path)`
- `static boolean isExecutable(Path path)`
- `static boolean isRegularFile(Path path)`
- `static boolean isDirectory(Path path)`
- `static boolean isSymbolicLink(Path path)`

  checks for the given property of the file given by the path.
- `static long size(Path path)`

  gets the size of the file in bytes.
- `A readAttributes(Path path, Class<A> type, LinkOption... options)`

  reads the file attributes of type `A`.

java.nio.file.attribute.BasicFileAttributes 7

- `FileTime creationTime()`
- `FileTime lastAccessTime()`
- `FileTime lastModifiedTime()`
- `boolean isRegularFile()`
- `boolean isDirectory()`
- `boolean isSymbolicLink()`
- `long size()`
- `Object fileKey()`

  gets the requested attribute.

Core Java, Volume II, Chapter 2

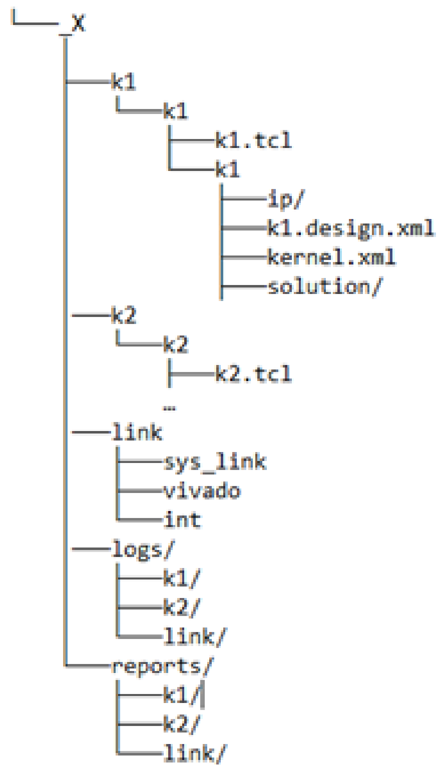
Visiting Directory Entries

`Files.list`

Does not enter subdirectories (i.e., only traverse the first-layer subdirectories)

```
Path dir = Paths.get(workingDir);

try(Stream<Path> entries = Files.list(dir)){
    entries.forEach(p -> System.out.println(p.toAbsolutePath()));
}
```



```
└──_X
   ├──k1
   │  └──k1
   │     ├──k1.tcl
   │     └──k1
   │        ├──ip/
   │        ├──k1.design.xml
   │        ├──kernel.xml
   │        └──solution/
   ├──k2
   │  └──k2
   │     ├──k2.tcl
   │     …
   ├──link
   │  ├──sys_link
   │  ├──vivado
   │  └──int
   ├──logs/
   │  ├──k1/
   │  ├──k2/
   │  └──link/
   └──reports/
      ├──k1/
      ├──k2/
      └──link/
```

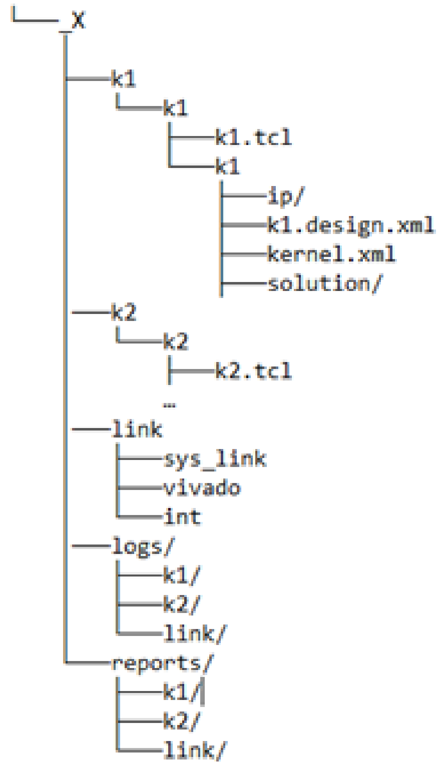
Visiting Directory Entries

`Files.walk`

Enter all subdirectories in a depth-first manner

```java
Path dir = Paths.get(workingDir);

try(Stream<Path> entries = Files.walk(dir)){
    entries.filter(Files::isRegularFile).forEach(System.out::println);
}
```



```
└──_X
   │
   ├──k1
   │  └──k1
   │     ├──k1.tcl
   │     └──k1
   │        ├──ip/
   │        ├──k1.design.xml
   │        ├──kernel.xml
   │        ├──solution/
   ├──k2
   │  └──k2
   │     ├──k2.tcl
   │     …
   ├──link
   │  ├──sys_link
   │  ├──vivado
   │  └──int
   ├──logs/
   │  ├──k1/
   │  ├──k2/
   │  └──link/
   └──reports/
      ├──k1/
      ├──k2/
      └──link/
```

Visiting Directory Entries

- You may also use walkFileTree method and supply an object of type `SimpleFileVisitor`, which gets notified
  - When a file is encountered (`visitFile`)
  - Before a directory is processed (`preVisitDirectory`)
  - After a directory is processed (`postVisitDirectory`)
  - When an error occurred (`visitFileFailed`)
- You may perform any actions you want for these events, and specify whether you want to
  - Continue visiting the next file (`FileVisitResult.CONTINUE`)
  - Continue but without visiting the entries in this directory(`FileVisitResult.SKIP_SUBTREE`)
  - Continue but without visiting the siblings of this file (`FileVisitResult.SKIP_SIBLINGS`)
  - Terminate the walk (`FileVisitResult.TERMINATE`)

Visiting Directory Entries

```
// Using the file visitor

Path path = Paths.get(".");
Files.walkFileTree(path, new ListFileVisitor());
```

```
class ListFileVisitor extends SimpleFileVisitor<Path> {

    @Override
    public FileVisitResult visitFile(Path file, BasicFileAttributes attributes) throws IOException {
        System.out.println("Visiting file:" + file.toRealPath());
        return FileVisitResult.CONTINUE;
    }

    @Override
    public FileVisitResult postVisitDirectory(Path directory, IOException e)
            throws IOException {
        System.out.println("Finished directory: "
                + directory.toRealPath());
        return FileVisitResult.CONTINUE;
    }

    @Override
    public FileVisitResult preVisitDirectory(Path directory,
                                             BasicFileAttributes attributes) throws IOException {
        System.out.println("Start directory: "
                + directory.toRealPath());
        return FileVisitResult.CONTINUE;
    }

    @Override
    public FileVisitResult visitFileFailed(Path file, IOException exc)
            throws IOException {
        System.out.println("An error occurred.");
        return FileVisitResult.SKIP_SUBTREE;
    }
}
```

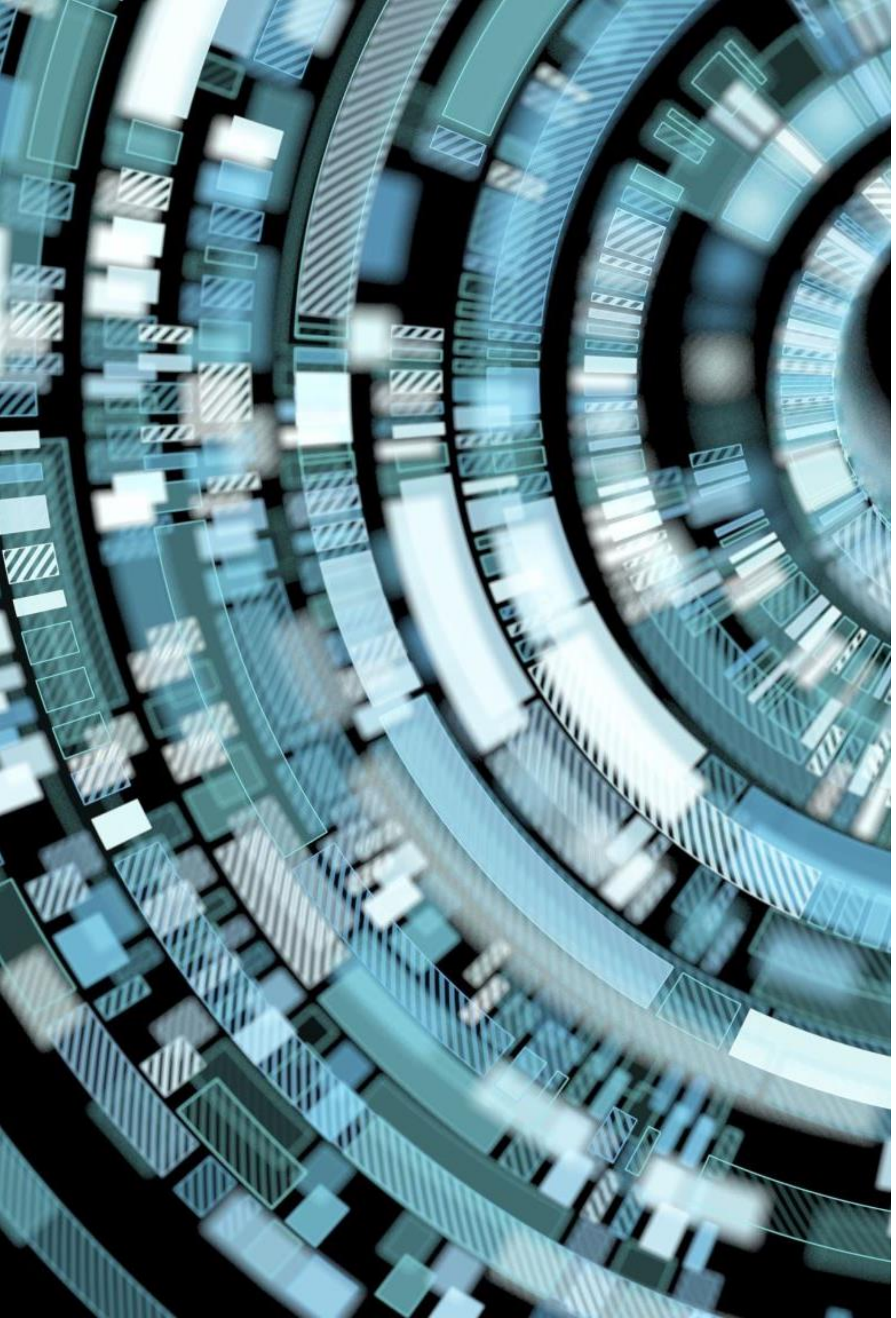
Reading Files Line by Line

```java
Path file = Paths.get("resources","math.txt");
System.out.println("Using Scanner:");
Scanner in = new Scanner(file);
while(in.hasNext()){
    System.out.println(in.nextLine());
}

System.out.println("Using Files.lines:");
try (Stream<String> stream = Files.lines(file)) {
    stream.forEach(System.out::println);
} catch (IOException e) {
    e.printStackTrace();
}

System.out.println("Using BufferedReader:");
try (BufferedReader br = Files.newBufferedReader(file)) {
    String line;
    while ((line = br.readLine()) != null) {
        System.out.println(line);
    }

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



Lecture 6

- Persistence and Serialization
- Working with Files
- Exception Handling

Exception

- An exception indicates that a problem occurs during a program's execution
- An exception disrupts the normal flow of the program

Happy Path

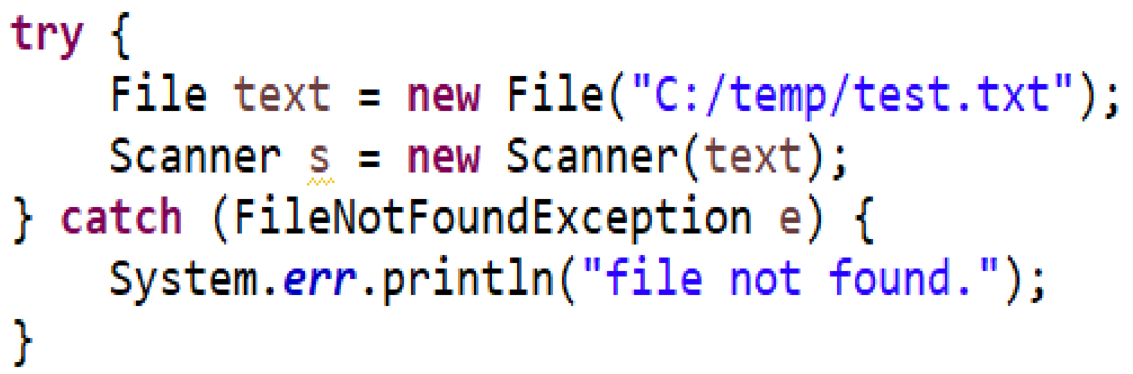
Files are always there
Network is always okay
Memory is always enough
User input is always valid
……

Unhappy Path

Files are not found
Network breaks down
Memory is not enough
User input is invalid
……

Exception Handling

- A mechanism to handle errors **gracefully** in order to maintain the normal flow of the program



```
try {
    File text = new File("C:/temp/test.txt");
    Scanner s = new Scanner(text);
} catch (FileNotFoundException e) {
    System.err.println("file not found.");
}
```

Detection

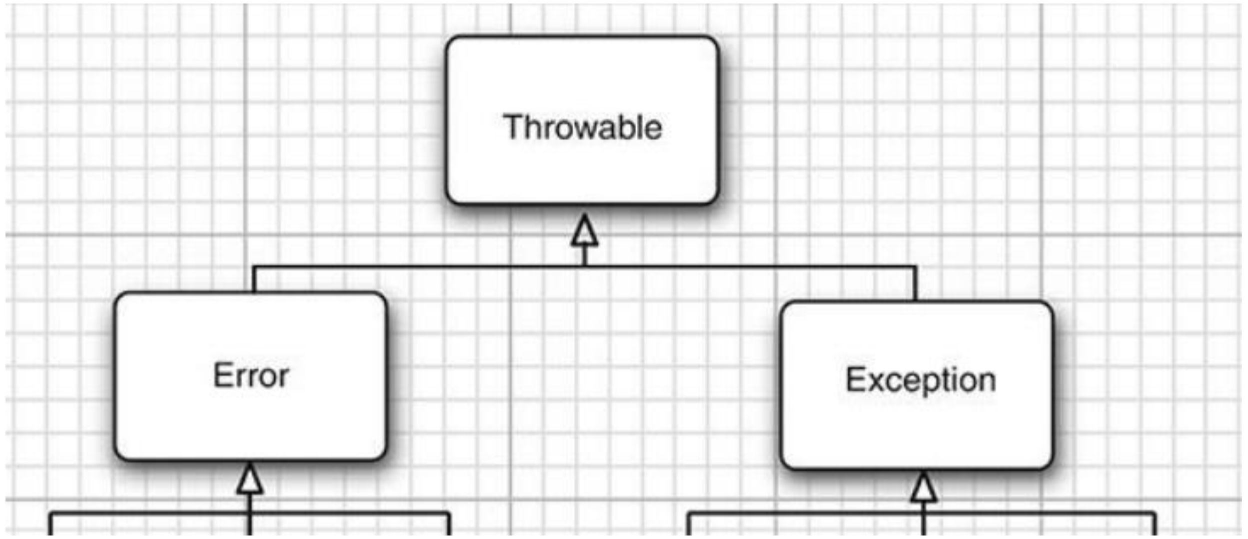
Handling

Exception handling passes control from the point of error detection to a handler that can deal with the error

Java Exception Hierarchy

Only `Throwable` or its subclasses

- Can be thrown by JVM or the `throw` keyword
- Can be caught by the `catch` keyword

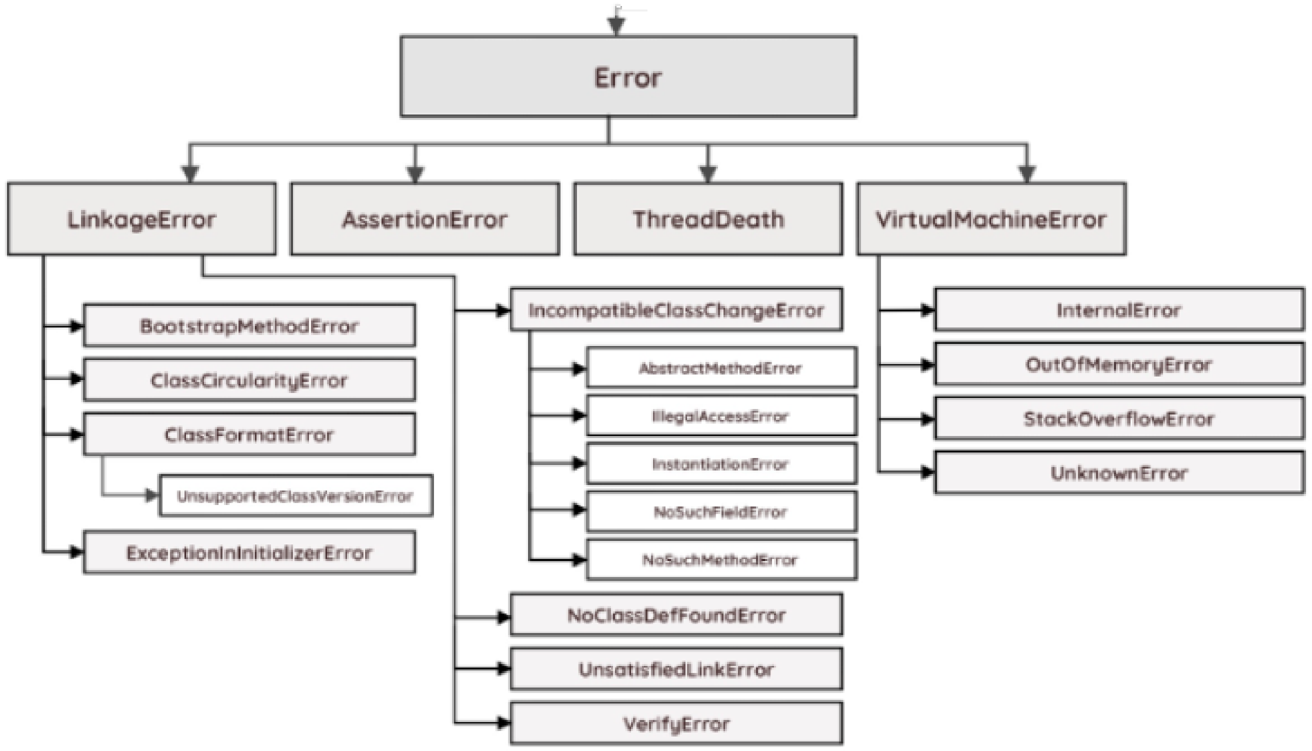


The Throwable class is at the top of the Java exception class hierarchy; has two direct subclass: Error and Exception

Error

- The Error hierarchy describes internal errors and resource exhaustion situations inside the Java runtime system.
- An error indicates serious problems that a reasonable application **should not** try to catch
- E.g., `OutofMemoryError`, `StackOverflowError`

Image source: https://rollbar.com/blog/java-exceptions-hierarchy-explained



Mostly thrown by JVM in a scenario considered fatal;
No way for the application to recover from that error

Example

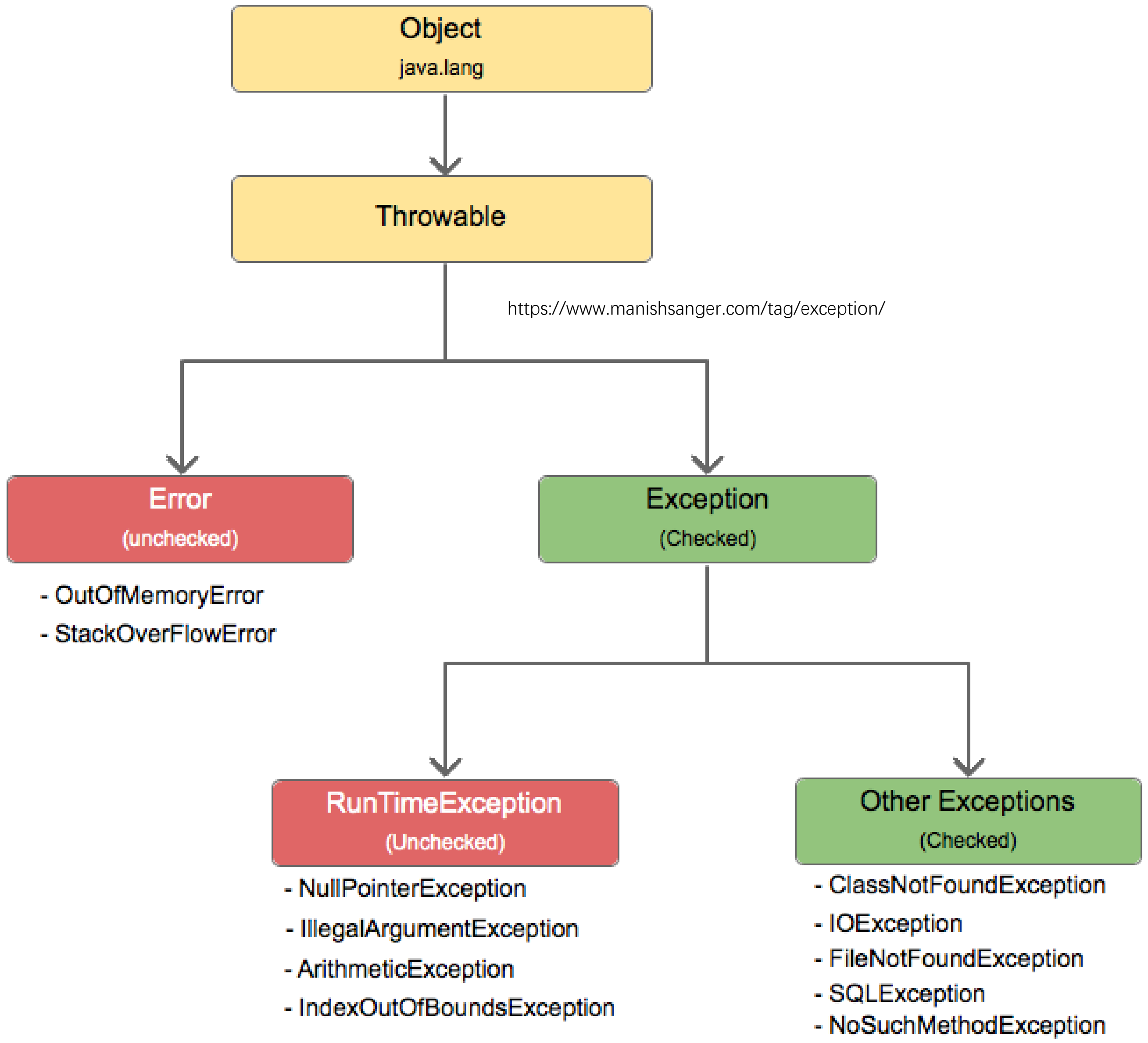
- What is the problem with `foo(String s)`?
- Stack is exhausted, leading to `StackOverflowError`
- No recovery during execution, just let it terminate

```
public void foo(String s)
{
        foo(s);
}
```

```
Exception in thread "main" java.lang.StackOverflowError
        at examples.foo(examples.java:58)
        at examples.foo(examples.java:58)
        at examples.foo(examples.java:58)
        at examples.foo(examples.java:58)
        at examples.foo(examples.java:58)
        at examples.foo(examples.java:58)
        at examples.foo(examples.java:58)
```

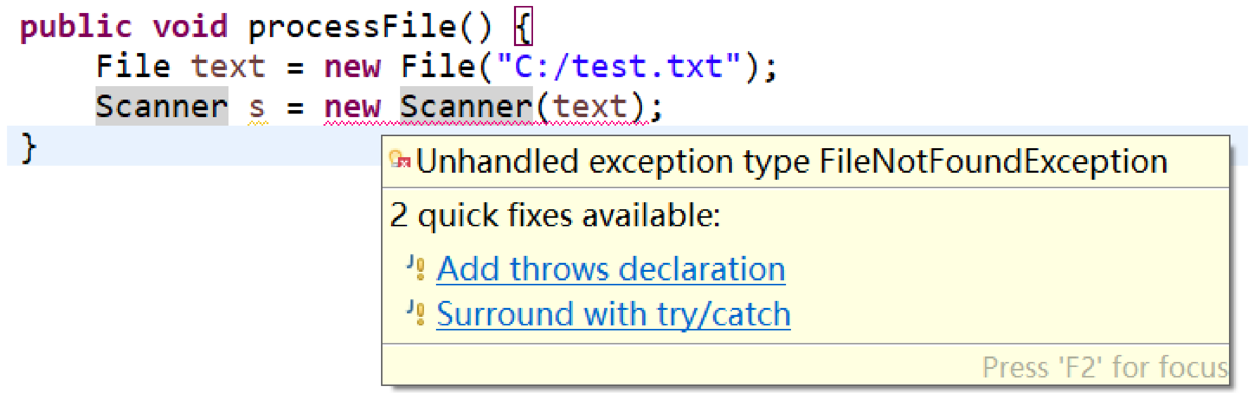
Exception

- An exception indicates a condition that a reasonable application might **want to** catch.
- RuntimeException and its subclasses are unchecked exceptions
- Others are checked exceptions (think of it as checked by compiler)



Checked Exceptions

- Checked Exceptions cannot be ignored at the time of compilation
- Compilers will enforce programmers to handle them
- Two fixes: catch or throw



```
public void processFile() {
    File text = new File("C:/test.txt");
    Scanner s = new Scanner(text);
}
```

Unhandled exception type FileNotFoundException

2 quick fixes available:

- Add throws declaration
- Surround with try/catch

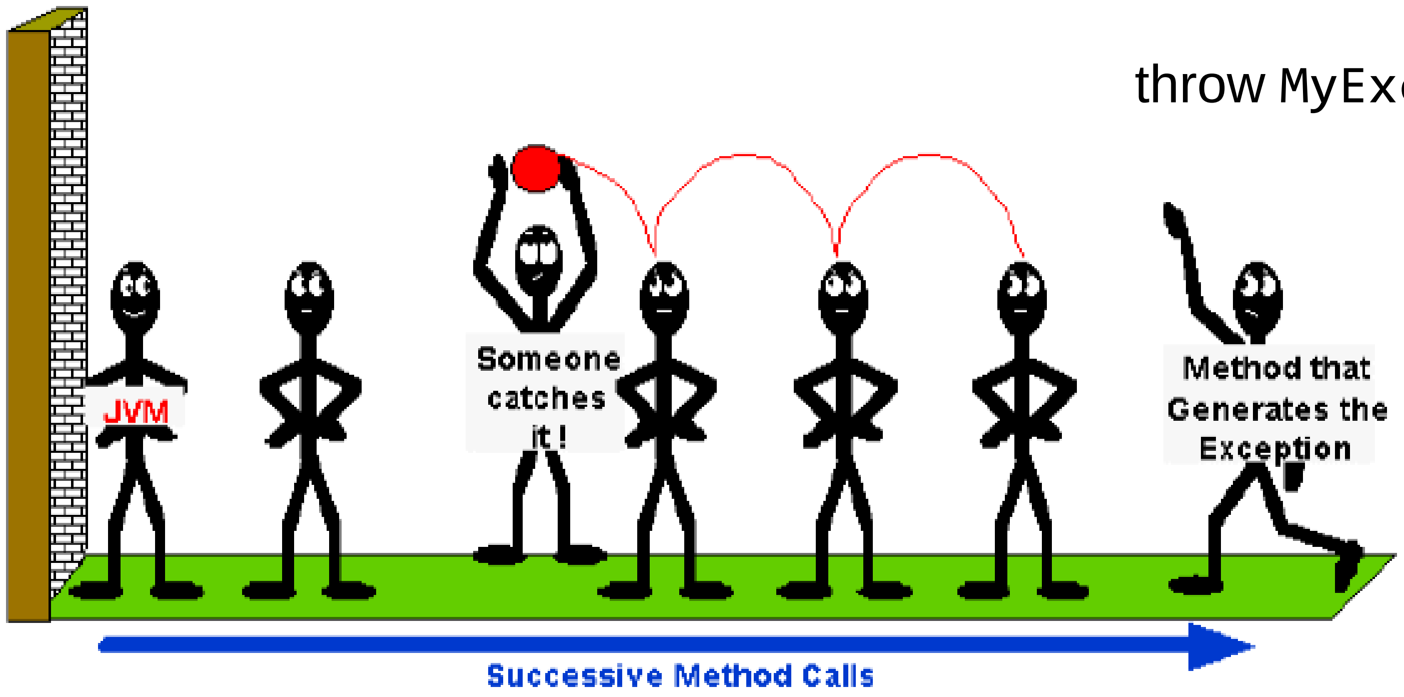
Press 'F2' for focus

```
public void processFile() {
    File text = new File("C:/test.txt");
    try {
        Scanner s = new Scanner(text);
    } catch (FileNotFoundException e) {
        System.out.println("Cannot find file xxx.");
    }
}
```

```
public void processFile() throws FileNotFoundException {
    File text = new File("C:/test.txt");
    Scanner s = new Scanner(text);
}
```

Throw & Catch

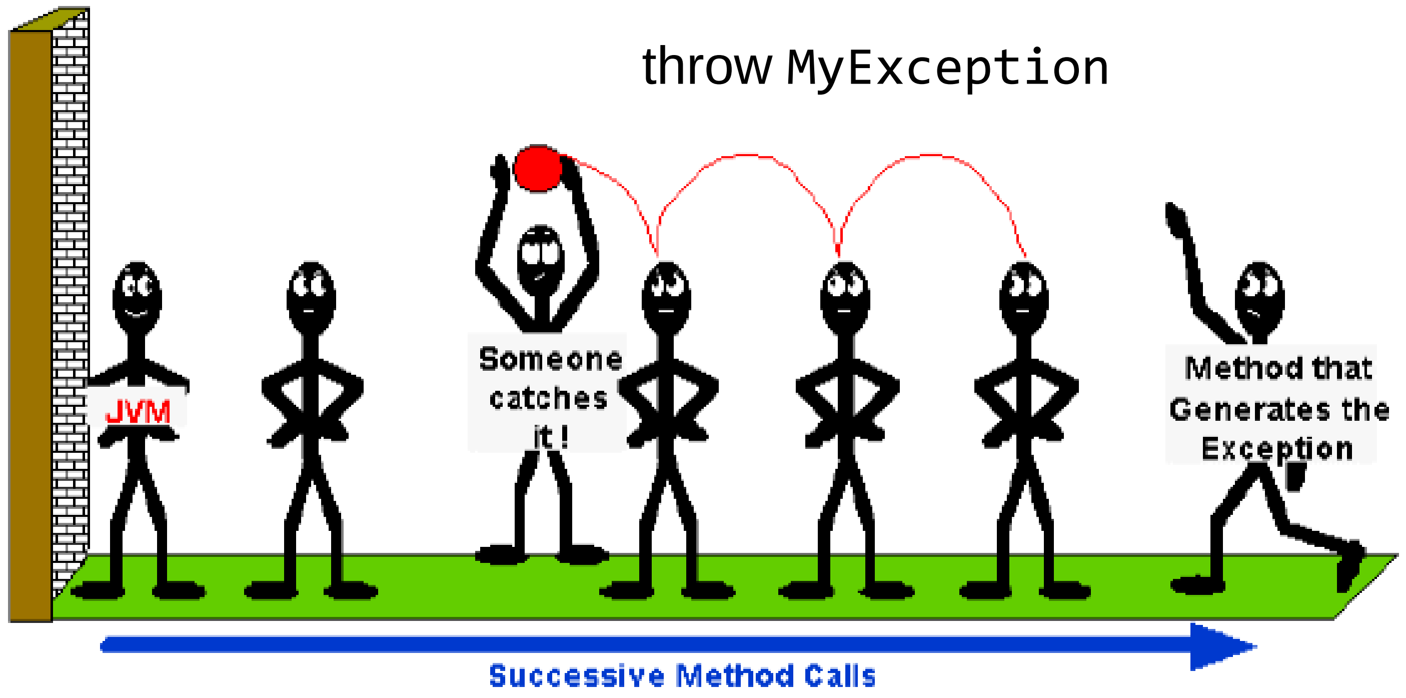
throw `MyException`



A() → B() → C() → D() → E() → F()

Throw & Catch

throw `MyException`

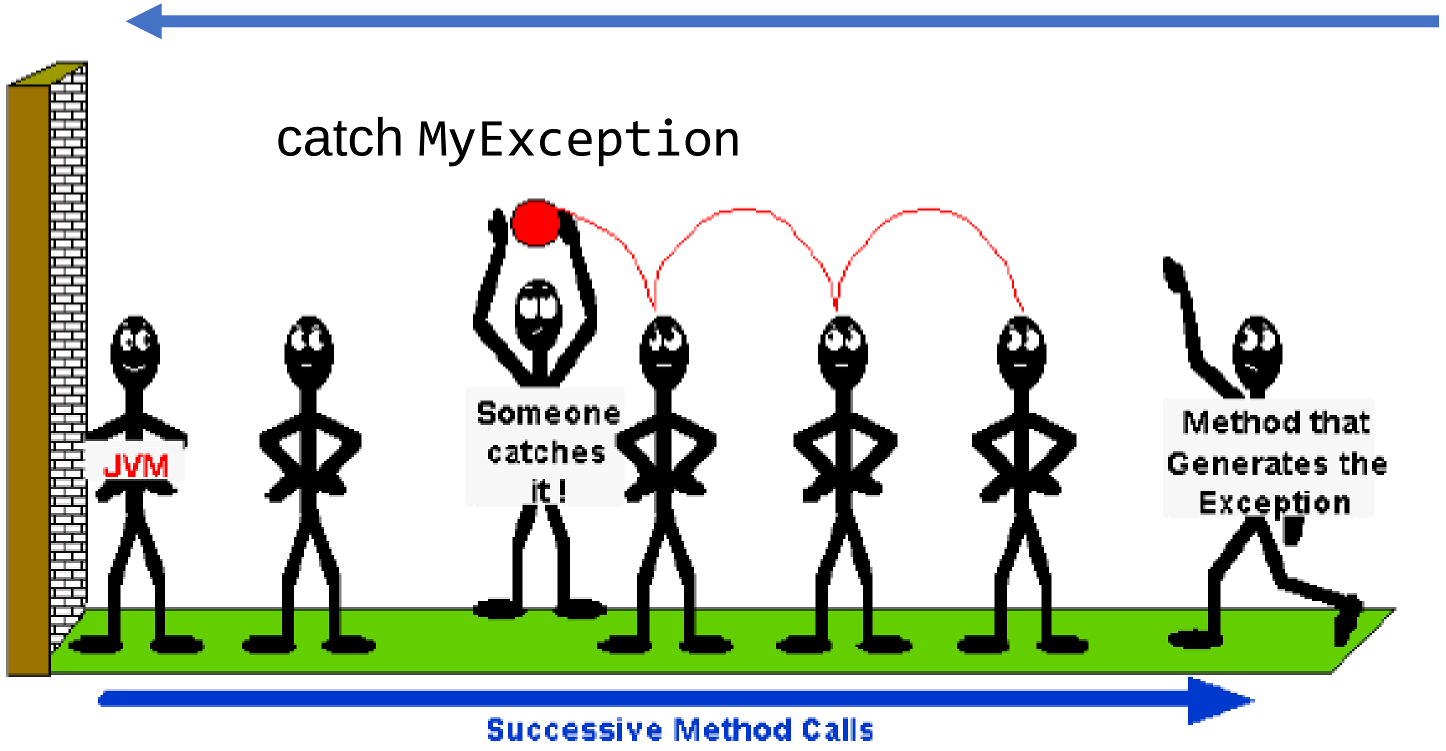


$$A() \rightarrow B() \rightarrow C() \rightarrow D() \rightarrow E() \rightarrow F()$$

Throw & Catch

JVM searches backward through the call stack to find a **matching `catch`** handler

catch `MyException`

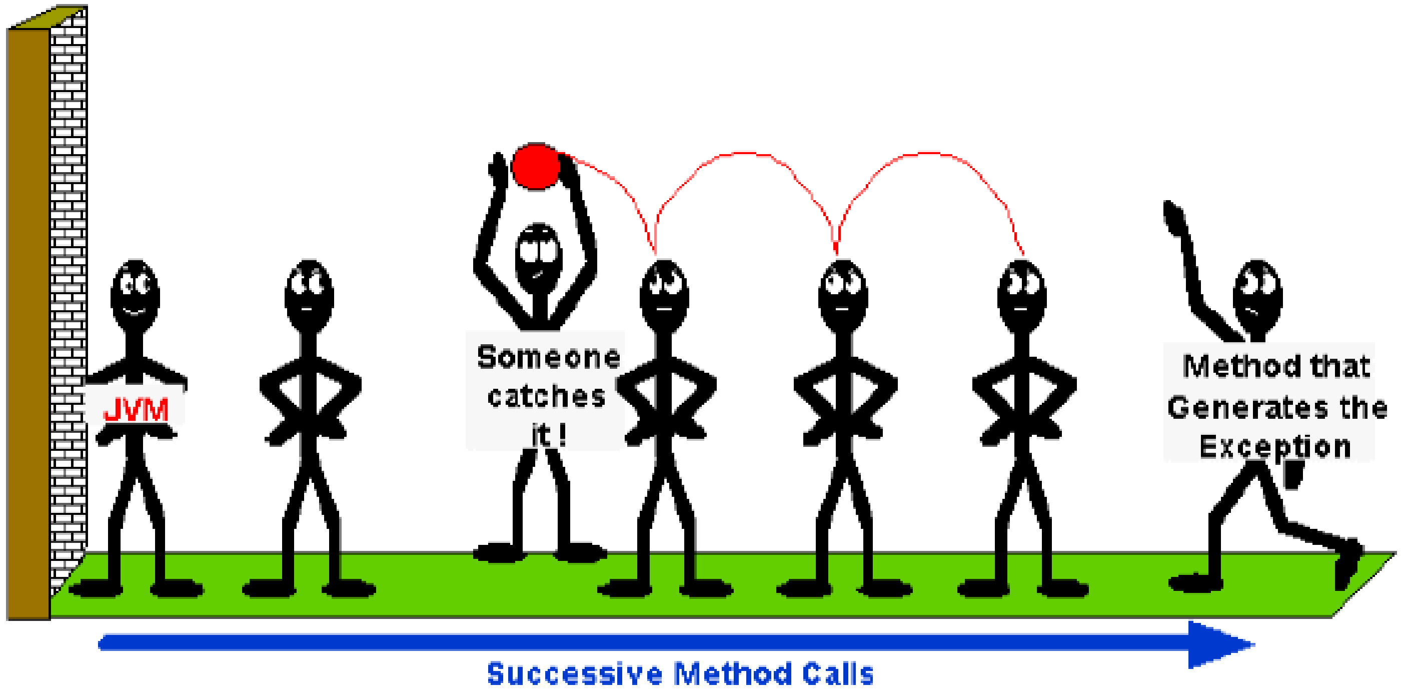


A() → B() → C() → D() → E() → F()

Where to throw, where to catch?

Catch exceptions if you know how to handle them

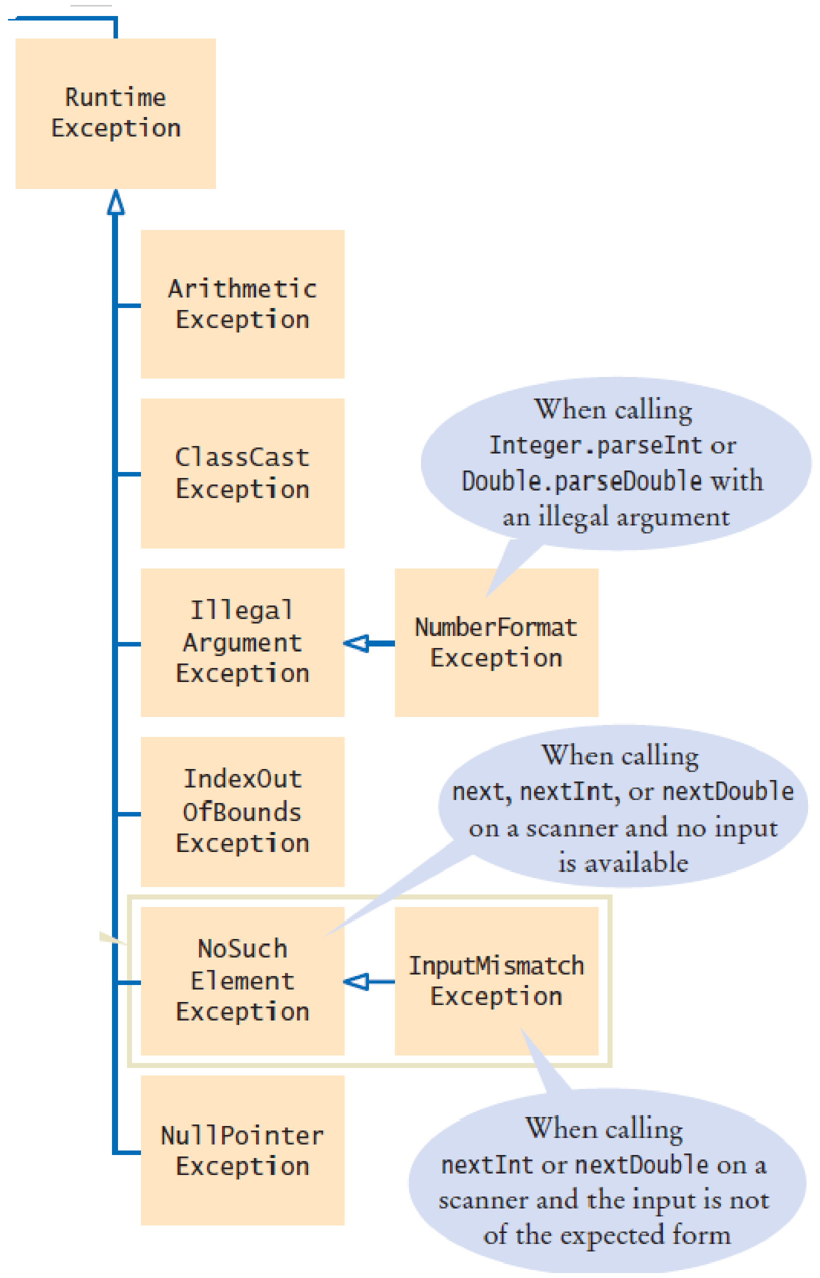
Throw exceptions that you do not know how to handle



A() → B() → C() → D() → E() → F()

Unchecked Exceptions

- Will not be checked by compilers
- Occur at runtime
- Usually caused by logic errors in programming
- E.g., `NullPointerException`, `IndexOutOfBoundsException`


RuntimeException
ArithmeticException
ClassCastException
IllegalArgumentException
NumberFormatException
When calling Integer.parseInt or Double.parseDouble with an illegal argument
IndexOutOfBoundsException
When calling next, nextInt, or nextDouble on a scanner and no input is available
NoSuchElementException
InputMismatchException
When calling nextInt or nextDouble on a scanner and the input is not of the expected form
NullPointerException

```java
try {
        // some code
} catch(FileNotFoundException e) {
    logger.log(e);

} catch(SQLException e) {
    logger.log(e);

} catch(SocketException e) {
    logger.log(e);
}
```

```java
try {
        // some code

} catch(FileNotFoundException
                | SQLException
                | SocketException e) {
    logger.log(e);

}
```

In Java 7 and later, a single catch block can handle multiple types of exception

Reduce code duplication

Avoid using overly broad exception

Catching Multiple Exceptions

```
try {
        // some code
} catch(FileNotFoundException e) {
    logger.log(e);

} catch(SQLException e) {
    logger.log(e);

} catch(SocketException e) {
    logger.log(e);
}
```

```
try {
        // some code

} catch(Exception e) {
    logger.log(e);

}
```

`catch (Exception e)` is often considered a bad practice

- It may not properly handle logics that required for specific exceptions
- It may catch unexpected exceptions
- It may mask the actual error and impeding debugging

Catching Multiple Exceptions

The `finally` Clause

- When your code throws an exception, it stops processing the remaining code
- Problem occurs if the remaining code does crucial operations such as close resources
- Put such logics in the `finally` clause, which always executes

```
Scanner scanner = null;
try {
    scanner = new Scanner(new File("test.txt"));
    while (scanner.hasNext()) {
        System.out.println(scanner.nextLine());
    }
} catch (FileNotFoundException e) {
    e.printStackTrace();
} finally {
    if (scanner != null) {
        scanner.close();
    }
}
```

The `finally` Clause

No exception:

1

2

5

6

```
var in = new FileInputStream(. . .);
try
{
   // 1
   code that might throw exceptions
   // 2
}
catch (IOException e)
{
   // 3
   show error message
   // 4
}
finally
{
   // 5
   in.close();
}
// 6
```

The `finally` Clause

1 throws IOException

1

3

4

5

6

```
var in = new FileInputStream(. . .);
try
{
   // 1
   code that might throw exceptions
   // 2
}
catch (IOException e)
{
   // 3
   show error message
   // 4
}
finally
{
   // 5
   in.close();
}
// 6
```

The `finally` Clause

1 throws IOException and 3 throws a new Exception

1

3

5

```
var in = new FileInputStream(. . .);
try
{
   // 1
   code that might throw exceptions
   // 2
}
catch (IOException e)
{
   // 3
   show error message
   // 4
}
finally
{
   // 5
   in.close();
}
// 6
```

The `finally` Clause

2 throws SQLException

1

2

5

```
var in = new FileInputStream(. . .);
try
{
   // 1
   code that might throw exceptions
   // 2
}
catch (IOException e)
{
   // 3
   show error message
   // 4
}
finally
{
   // 5
   in.close();
}
// 6
```

try-with-resources

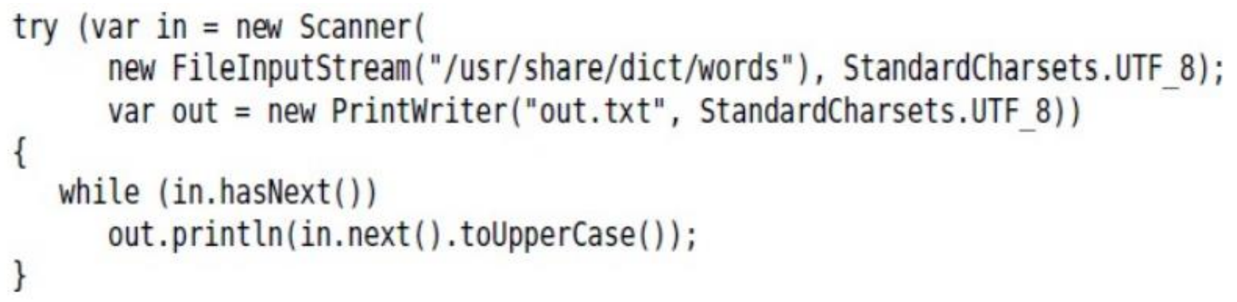
`try-with-resources` statement ensures that a resource (e.g., InputStream, database connection) is automatically closed after the program is finished with it

```
open a resource
try
{
   work with the resource
}
finally
{
   close the resource
}
```

```
try (Resource res = . . .)
{
   work with res
}
```

try-with-resources

`try-with-resources` statement ensures that a resource (e.g., InputStream, database connection) is automatically closed after the program is finished with it



```
try (var in = new Scanner(
        new FileInputStream("/usr/share/dict/words"), StandardCharsets.UTF_8);
        var out = new PrintWriter("out.txt", StandardCharsets.UTF_8))
{
   while (in.hasNext())
      out.println(in.next().toUpperCase());
}
```

No matter how the block exits, both `in` and `out` are closed.

Next Lecture

- Multithreading