Concepts of exception handling

Exceptions

- Exception is an abnormal condition that arises when executing a program.
- In the languages that do not support exception handling, errors must be checked and handled manually, usually through the use of error codes.
- In contrast, Java:
  1) provides syntactic mechanisms to signal, detect and handle errors
  2) ensures a clean separation between the code executed in the

  absence of errors and the code to handle various kinds of errors
  3) brings run-time error management into object-oriented programming

Exception Handling

- An exception is an object that describes an exceptional condition (error) that has occurred when executing a program.
- Exception handling involves the following:
  1) when an error occurs, an object (exception) representing this error is created and thrown in the method that caused it
  2) that method may choose to handle the exception itself or pass it on
  3) either way, at some point, the exception is caught and processed

Exception Sources

- Exceptions can be:

  1) generated by the Java run-time system Fundamental errors that violate the rules of the Java language or the constraints of the Java execution environment.

  2) manually generated by programmer's code Such exceptions are typically used to report some error conditions to the caller of a method.

Exception Constructs

- Five constructs are used in exception handling:
  1) try – a block surrounding program statements to monitor for exceptions
  2) catch – together with try, catches specific kinds of exceptions and handles them in some way
  3) finally – specifies any code that absolutely must be executed whether or not an exception occurs
  4) throw – used to throw a specific exception from the program
  5) throws – specifies which exceptions a given method can throw

Exception-Handling Block

General form:

```
try { … }
catch(Exception1 ex1) { … }
catch(Exception2 ex2) { … }
…
finally { … }
```

where:

1) try { … } is the block of code to monitor for exceptions
2) catch(Exception ex) { … } is exception handler for the exception Exception
3) finally { … } is the block of code to execute before the try block ends

Benefits of exception handling

- Separating Error-Handling code from “regular” business logic code
- Propagating errors up the call stack
- Grouping and differentiating error types

Separating Error Handling Code from Regular Code

In traditional programming, error detection, reporting, and handling often lead to confusing code

Consider 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;
}
```

Traditional Programming: No separation of error handling code

- In traditional programming, To handle such cases, the *readFile* function must have more code to do error detection, reporting, and 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;
    }
  } else {
    errorCode = -3;
    }
    close the file;
    if (theFileDidntClose && errorCode == 0) {
    errorCode = -4;
    } else {
    errorCode = errorCode and -4;
    }
    } else {
    errorCode = -5;
    }
    return errorCode;
    }
```

Separating Error Handling Code from Regular Code (in Java)

Exceptions enable you to write the main flow of your code and to deal with the exceptional cases elsewhere

```
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.

Propagating Errors Up the Call Stack

- 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*
- Suppose also that method1 is the only method interested in the errors that might occur within *readFile*.

```
method1 {
call method2;
}
method2 {
call method3;
}
method3 {
call readFile;
}
```

Traditional Way of Propagating Errors

```
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;
}
```

- 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.

Using Java Exception Handling

```
method1 {
try {
call method2;
} catch (exception e) {
doErrorProcessing;
}
}
method2 throws exception {
call method3;
}
method3 throws exception {
call readFile;
}
```

❖ Any checked exceptions that can be thrown within a method must be specified in its throws clause.

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 super classes 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 all I/O exceptions, including
// FileNotFoundException, EOFException, and so
   on.
catch (IOException e) {
...
```

Termination vs. resumption

- There are two basic models in exception-handling theory.
- In *termination* the error is so critical there's no way to get back to where the exception occurred. Whoever threw the exception decided that there was no way to salvage the situation, and they don't *want* to come back.
- The alternative is called *resumption*. It means that the exception handler is expected to do something to rectify the situation, and then the faulting method is retried, presuming success the second time. If you want resumption, it means you still hope to continue execution after the exception is handled.

- In resumption a method call that want resumption-like behavior (i.e don't throw an exception all a method that fixes the problem.)
- Alternatively, place your **try** block inside a **while** loop that keeps reentering the **try** block until the result is satisfactory.
- Operating systems that supported resumptive exception handling eventually ended up using termination-like code and skipping

Exception Hierarchy

- All exceptions are sub-classes of the build-in class Throwable.
- Throwable contains two immediate sub-classes:

1) Exception – exceptional conditions that programs should catch

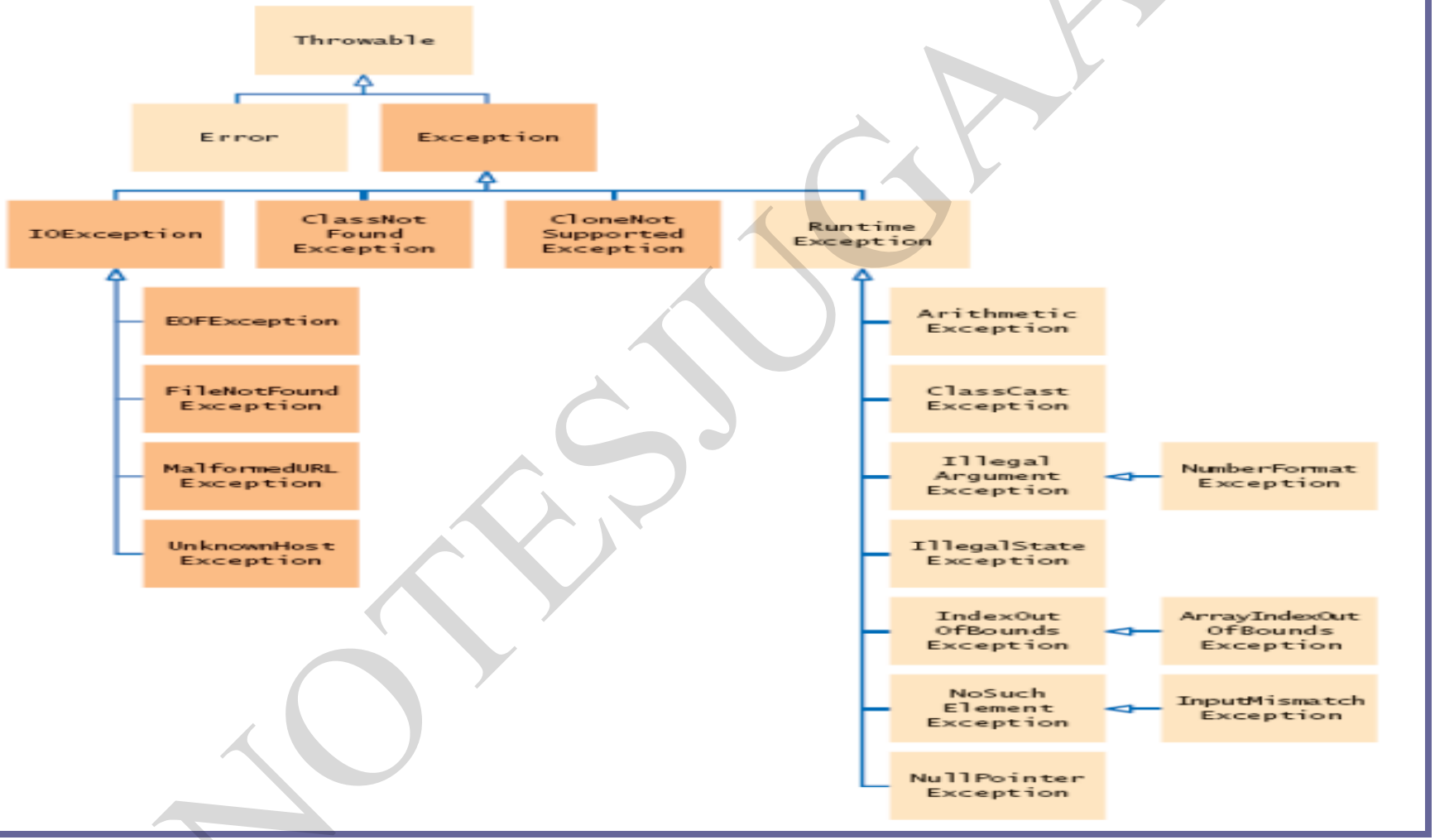
   The class includes:

   a) RuntimeException – defined automatically for user programs to include: division by zero, invalid array indexing, etc.

   b) use-defined exception classes

2) Error – exceptions used by Java to indicate errors with the runtime environment; user programs are not supposed to catch them

Hierarchy of Exception Classes



Usage of *try-catch* Statements

- Syntax:

```
try {
<code to be monitored for exceptions>
} catch (<ExceptionType1> <ObjName>) {
<handler if ExceptionType1 occurs>
} ...
} catch (<ExceptionTypeN> <ObjName>) {
<handler if ExceptionTypeN occurs>
}
```

Catching Exceptions: The *try-catch* Statements

```
class DivByZero {
public static void main(String args[]) {
try {
System.out.println(3/0);
System.out.println("Please print me.");
} catch (ArithmeticException exc) {
//Division by zero is an ArithmeticException
System.out.println(exc);
}
System.out.println("After exception.");
}
}
```

Catching Exceptions: Multiple catch

```
class MultipleCatch {
public static void main(String args[]) {
try {
int den = Integer.parseInt(args[0]);
System.out.println(3/den);
} catch (ArithmeticException exc) {
System.out.println("Divisor was 0.");
} catch (ArrayIndexOutOfBoundsException exc2) {
System.out.println("Missing argument.");
}
System.out.println("After exception.");
}
}
```

Catching Exceptions: Nested try's

```
class NestedTryDemo {
public static void main(String args[]){
try {
int a = Integer.parseInt(args[0]);
try {
int b = Integer.parseInt(args[1]);
System.out.println(a/b);
} catch (ArithmeticException e) {
System.out.println(“Div by zero error!");
} } catch (ArrayIndexOutOfBoundsException) {
System.out.println(“Need 2 parameters!");
} }   }
```

Catching Exceptions: Nested try's with methods

```
class NestedTryDemo2 {
 static void nestedTry(String args[]) {
 try {
 int a = Integer.parseInt(args[0]);
 int b = Integer.parseInt(args[1]);
 System.out.println(a/b);
 } catch (ArithmeticException e) {
System.out.println("Div by zero error!");
 }    }
public static void main(String args[]){
 try {
 nestedTry(args);
 } catch (ArrayIndexOutOfBoundsException e) {
 System.out.println("Need 2 parameters!");
 }  }   }
```

Throwing Exceptions(throw)

- So far, we were only catching the exceptions thrown by the Java system.
- In fact, a user program may throw an exception explicitly:

  throw ThrowableInstance;

- ThrowableInstance must be an object of type Throwable or its subclass.

Once an exception is thrown by:

throw ThrowableInstance;

1) the flow of control stops immediately
2) the nearest enclosing try statement is inspected if it has a catch statement that matches the type of exception:

1) if one exists, control is transferred to that statement
2) otherwise, the next enclosing try statement is examined
3) if no enclosing try statement has a corresponding catch clause, the default exception handler halts the program and prints the stack

Creating Exceptions

Two ways to obtain a Throwable instance:

1) creating one with the new operator

All Java built-in exceptions have at least two Constructors:

One without parameters and another with one String parameter:

```
throw new NullPointerException("demo");
```

2) using a parameter of the catch clause

```
try { … } catch(Throwable e) { … e … }
```

Example: throw 1

```
class ThrowDemo {
//The method demoproc throws a NullPointerException
  exception which is immediately caught in the try block and
  re-thrown:
static void demoproc() {
try {
throw new NullPointerException("demo");
} catch(NullPointerException e) {
System.out.println("Caught inside demoproc.");
throw e;
}
}
```

Example: throw 2

The main method calls demoproc within the try block which catches and handles the NullPointerException exception:

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

throws Declaration

- If a method is capable of causing an exception that it does not handle, it must specify this behavior by the throws clause in its declaration:

  type name(parameter-list) throws exception-list {

  …

  }
- where exception-list is a comma-separated list of all types of exceptions that a method might throw.
- All exceptions must be listed except Error and

Example: throws 1

- The throwOne method throws an exception that it does not catch, nor declares it within the throws clause.

```
class ThrowsDemo {
static void throwOne() {
System.out.println("Inside throwOne.");
throw new IllegalAccessException("demo");
}
public static void main(String args[]) {
throwOne();
}
}
```

- Therefore this program does not compile.

Example: throws 2

- Corrected program: throwOne lists exception, main catches it:

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

finally

- When an exception is thrown:

  1) the execution of a method is changed

  2) the method may even return prematurely.
- This may be a problem is many situations.
- For instance, if a method opens a file on entry and closes on exit; exception handling should not bypass the proper closure of the file.
- The finally block is used to address this problem.

finally Clause

- The try/catch statement requires at least one catch or finally clause, although both are optional:

```
try { … }
catch(Exception1 ex1) { … } …
finally { … }
```

- Executed after try/catch whether of not the exception is thrown.
- Any time a method is to return to a caller from inside the try/catch block via:

  1) uncaught exception or

  2) explicit return

  the finally clause is executed just before the method returns.

Example: finally 1

- Three methods to exit in various ways.

```
class FinallyDemo {
//procA prematurely breaks out of the try by throwing an
   exception, the finally clause is executed on the way out:
static void procA() {
try {
System.out.println("inside procA");
throw new RuntimeException("demo");
} finally {
System.out.println("procA's finally");
}  }
```

Example: finally 2

// procB's try statement is exited via a return statement, the finally clause is executed before procB returns:

```
static void procB() {
try {
System.out.println("inside procB");
return;
} finally {
System.out.println("procB's finally");
}
}
```

Example: finally 3

- In procC, the try statement executes normally without error, however the finally clause is still executed:

```
static void procC() {
try {
System.out.println("inside procC");
} finally {
System.out.println("procC's finally");
}
}
```

Example: finally 4

- Demonstration of the three methods:

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

Java Built-In Exceptions

- The default java.lang package provides several exception classes, all sub-classing the

  RuntimeException class.
- Two sets of build-in exception classes:

  1) unchecked exceptions – the compiler does not check if a method handles or throws there exceptions

  2) checked exceptions – must be included in the method's throws clause if the method generates but does not handle them

Unchecked Built-In Exceptions

- Methods that generate but do not handle those exceptions need not declare them in the throws clause:

1) ArithmeticException
2) ArrayIndexOutOfBoundsException
3) ArrayStoreException
4) ClassCastException
5) IllegalStateException
6) IllegalMonitorStateException
7) IllegalArgumentException

8. StringIndexOutOfBounds
9. UnsupportedOperationException
10. SecurityException
11. NumberFormatException
12. NullPointerException
13. NegativeArraySizeException
14. IndexOutOfBoundsException
15. IllegalThreadStateException

Checked Built-In Exceptions

- Methods that generate but do not handle those exceptions must declare them in the throws clause:

1. NoSuchMethodException
   NoSuchFieldException
2. InterruptedException
3. InstantiationException
4. IllegalAccessException
5. CloneNotSupportedException

Creating Own Exception Classes

- Build-in exception classes handle some generic errors.
- For application-specific errors define your own exception classes. How? Define a subclass of Exception:

  class MyException extends Exception { … }

- MyException need not implement anything – its mere existence in the type system allows to use its objects as exceptions.

Example: Own Exceptions 1

- A new exception class is defined, with a private detail variable, a one parameter constructor and an overridden toString method:

```
class MyException extends Exception {
private int detail;
MyException(int a) {
detail = a;
}
public String toString() {
return "MyException[" + detail + "]";
}
}
```

Example: Own Exceptions 2

```
class ExceptionDemo {
The static compute method throws the MyException
exception whenever its a argument is greater than 10:
static void compute(int a) throws MyException {
System.out.println("Called compute(" + a + ")");
if (a > 10) throw new MyException(a);
System.out.println("Normal exit");
}
```

Example: Own Exceptions 3

The main method calls compute with two arguments

within a try block that catches the MyException exception:

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

Differences between multi threading and multitasking

Multi-Tasking

- Two kinds of multi-tasking:
  1) process-based multi-tasking
  2) thread-based multi-tasking
- Process-based multi-tasking is about allowing several programs to execute concurrently, e.g. Java compiler and a text editor.
- Processes are heavyweight tasks:
  1) that require their own address space
  2) inter-process communication is expensive and limited
  3) context-switching from one process to another is expensive and limited

Thread-Based Multi-Tasking

- Thread-based multi-tasking is about a single program executing concurrently
- several tasks e.g. a text editor printing and spell-checking text.
- Threads are lightweight tasks:

  1) they share the same address space

  2) they cooperatively share the same process

  3) inter-thread communication is inexpensive

  4) context-switching from one thread to another is low-cost
- Java multi-tasking is thread-based.

Reasons for Multi-Threading

- Multi-threading enables to write efficient programs that make the maximum use of the CPU, keeping the idle time to a minimum.
- There is plenty of idle time for interactive, networked applications:

  1) the transmission rate of data over a network is much slower than the rate at which the computer can process it

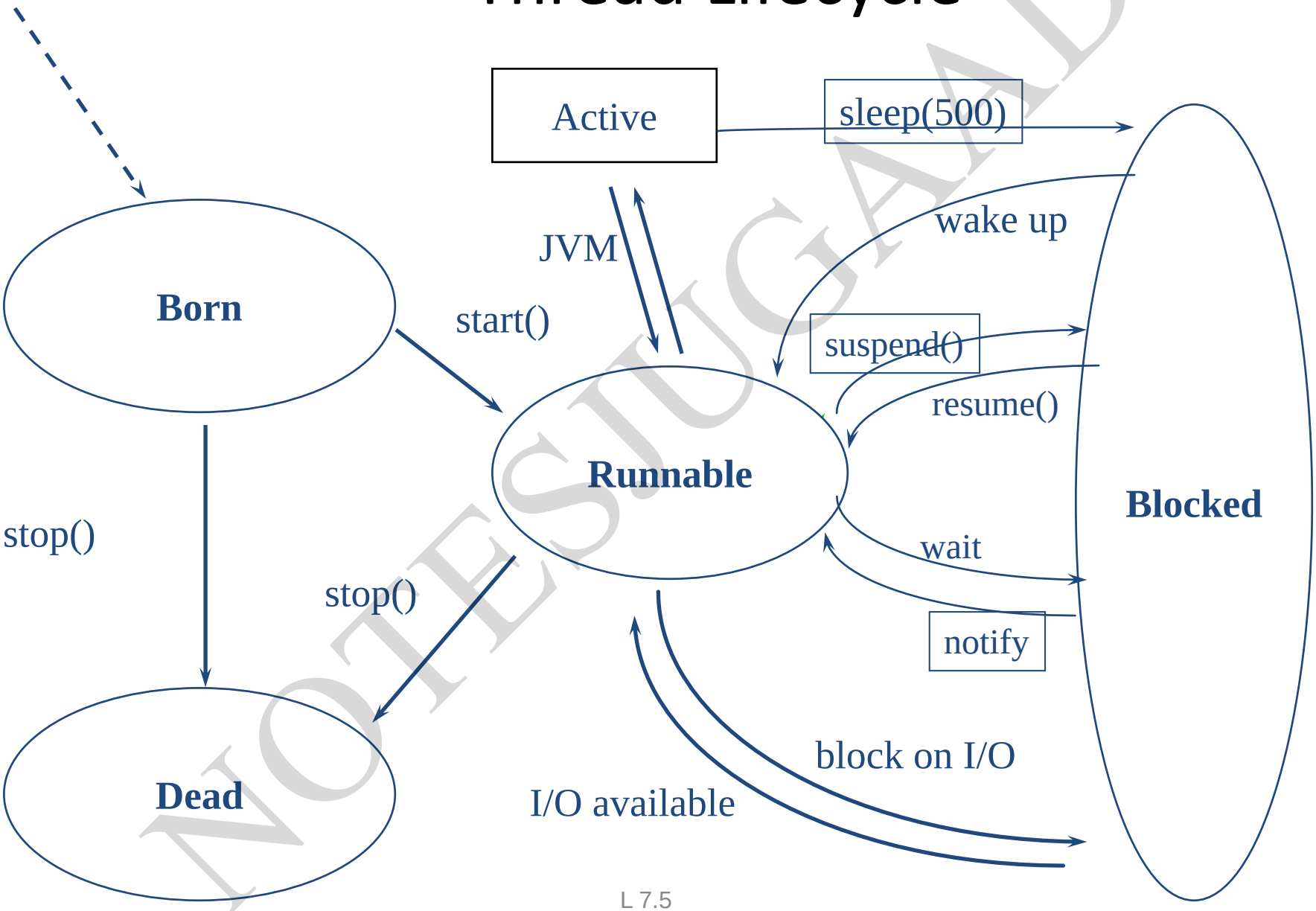
  2) local file system resources can be read and written at a much slower rate than can be processed by the CPU

  3) of course, user input is much slower than the computer

Thread Lifecycle

- Thread exist in several states:
  1) ready to run
  2) running
  3) a running thread can be suspended
  4) a suspended thread can be resumed
  5) a thread can be blocked when waiting for a resource
  6) a thread can be terminated
- Once terminated, a thread cannot be resumed.

Thread Lifecycle



- **New state –** After the creations of Thread instance the thread is in this state but before the start() method invocation. At this point, the thread is considered not alive.
- **Runnable (Ready-to-run) state –** A thread start its life from Runnable state. A thread first enters runnable state after the invoking of start() method but a thread can return to this state after either running, waiting, sleeping or coming back from blocked state also. On this state a thread is waiting for a turn on the processor.
- **Running state –** A thread is in running state that means the thread is currently executing. There are several ways to enter in Runnable state but there is only one way to enter in Running state: the scheduler select a thread from runnable pool.
- **Dead state –** A thread can be considered dead when its run() method completes. If any thread comes on this state that means it cannot ever run again.
- **Blocked -** A thread can enter in this state because of waiting the resources that are hold by another thread.

Creating Threads

- To create a new thread a program will:

  1) extend the Thread class, or

  2) implement the Runnable interface
- Thread class encapsulates a thread of execution.
- The whole Java multithreading environment is based on the Thread class.

Thread Methods

- Start: a thread by calling start its run method
- Sleep: suspend a thread for a period of time
- Run: entry-point for a thread
- Join: wait for a thread to terminate
- isAlive: determine if a thread is still running
- getPriority: obtain a thread's priority
- getName: obtain a thread's name

New Thread: Runnable

- To create a new thread by implementing the Runnable interface:

  1) create a class that implements the run method (inside this method, we define the code that constitutes the new thread):

  public void run()

  2) instantiate a Thread object within that class, a possible constructor is:

  Thread(Runnable threadOb, String threadName)

  3) call the start method on this object (start calls run):

  void start()

Example: New Thread 1

- A class NewThread that implements Runnable:

```
class NewThread implements Runnable {
Thread t;
//Creating and starting a new thread. Passing this to
   the
// Thread constructor – the new thread will call this
// object's run method:
NewThread() {
t = new Thread(this, "Demo Thread");
System.out.println("Child thread: " + t);
t.start();
}
```

Example: New Thread 2

```
//This is the entry point for the newly created thread – a five-iterations loop
//with a half-second pause between the iterations all within try/catch:
public void run() {
try {
for (int i = 5; i > 0; i--) {
System.out.println("Child Thread: " + i);
Thread.sleep(500);
}
} catch (InterruptedException e) {
System.out.println("Child interrupted.");
}
System.out.println("Exiting child thread.");
}
}
```

Example: New Thread 3

```
class ThreadDemo {
public static void main(String args[]) {
//A new thread is created as an object of
// NewThread:
new NewThread();
//After calling the NewThread start method,
// control returns here.
```

Example: New Thread 4

```
//Both threads (new and main) continue concurrently.
//Here is the loop for the main thread:
try {
for (int i = 5; i > 0; i--) {
System.out.println("Main Thread: " + i);
Thread.sleep(1000);
}
} catch (InterruptedException e) {
System.out.println("Main thread interrupted.");
}
System.out.println("Main thread exiting.");
}
}
```

New Thread: Extend Thread

- The second way to create a new thread:
  1) create a new class that extends Thread
  2) create an instance of that class
- Thread provides both run and start methods:
  1) the extending class must override run
  2) it must also call the start method

Example: New Thread 1

- The new thread class extends Thread:

```
class NewThread extends Thread {
//Create a new thread by calling the Thread's
// constructor and start method:
NewThread() {
super("Demo Thread");
System.out.println("Child thread: " + this);
start();
}
```

Example: New Thread 2

NewThread overrides the Thread's run method:

```
public void run() {
try {
for (int i = 5; i > 0; i--) {
System.out.println("Child Thread: " + i);
Thread.sleep(500);
}
} catch (InterruptedException e) {
System.out.println("Child interrupted.");
}
System.out.println("Exiting child thread.");
}
}
```

Example: New Thread 3

```
class ExtendThread {
public static void main(String args[]) {
//After a new thread is created:
new NewThread();
//the new and main threads continue
//concurrently…
```

Example: New Thread 4

```
//This is the loop of the main thread:
try {
for (int i = 5; i > 0; i--) {
System.out.println("Main Thread: " + i);
Thread.sleep(1000);
}
} catch (InterruptedException e) {
System.out.println("Main thread interrupted.");
}
System.out.println("Main thread exiting.");
}
}
```

Threads: Synchronization

- Multi-threading introduces asynchronous behavior to a program.
- How to ensure synchronous behavior when we need it?
- For instance, how to prevent two threads from simultaneously writing and reading the same object?
- Java implementation of monitors:

  1) classes can define so-called synchronized methods

  2) each object has its own implicit monitor that is automatically entered when one of the object's synchronized methods is called

  3) once a thread is inside a synchronized method, no other thread can call any other synchronized method on the same object

Thread Synchronization

- Language keyword: `synchronized`
- Takes out a monitor lock on an object
  - Exclusive lock for that thread
- If lock is currently unavailable, thread will block

Thread Synchronization

- Protects access to code, not to data
  - Make data members private
  - Synchronize accessor methods
- Puts a “force field” around the locked object so no other threads can enter
    - Actually, it only blocks access to other synchronizing threads

Daemon Threads

- Any Java thread can be a *daemon* thread.
- Daemon threads are service providers for other threads running in the same process as the daemon thread.
- The run() method for a daemon thread is typically an infinite loop that waits for a service request. When the only remaining threads in a process are daemon threads, the interpreter exits. This makes sense because when only daemon threads remain, there is no other thread for which a daemon thread can provide a service.
- To specify that a thread is a daemon thread, call the setDaemon method with the argument true. To determine if a thread is a daemon thread, use the accessor method isDaemon.

Thread Groups

- Every Java thread is a member of a *thread group*.
- Thread groups provide a mechanism for collecting multiple threads into a single object and manipulating those threads all at once, rather than individually.
- For example, you can start or suspend all the threads within a group with a single method call.
- Java thread groups are implemented by the “ThreadGroup” class in the java.lang package.
- The runtime system puts a thread into a thread group during thread construction.
- When you create a thread, you can either allow the runtime system to put the new thread in some reasonable default group or you can explicitly set the new thread's group.
- The thread is a permanent member of whatever thread group it joins upon its creation--you cannot move a thread to a new group after the thread has been created

The ThreadGroup Class

- The “ThreadGroup” class manages groups of threads for Java applications.
- A ThreadGroup can contain any number of threads.
- The threads in a group are generally related in some way, such as who created them, what function they perform, or when they should be started and stopped.
- ThreadGroups can contain not only threads but also other ThreadGroups.
- The top-most thread group in a Java application is the thread group named main.
- You can create threads and thread groups in the main group.
- You can also create threads and thread groups in subgroups of main.

Creating a Thread Explicitly in a Group

- A thread is a permanent member of whatever thread group it joins when its created--you cannot move a thread to a new group after the thread has been created. Thus, if you wish to put your new thread in a thread group other than the default, you must specify the thread group explicitly when you create the thread.
- The Thread class has three constructors that let you set a new thread's group:

  public Thread(ThreadGroup *group*, Runnable *target*) public Thread(ThreadGroup *group*, String *name*) public Thread(ThreadGroup *group*, Runnable *target*, String *name*)
- Each of these constructors creates a new thread, initializes it based on the Runnable and String parameters, and makes the new thread a member of the specified group.

  For example:

  ```
  ThreadGroup myThreadGroup = new ThreadGroup("My Group of Threads");
  Thread myThread = new Thread(myThreadGroup, "a thread for my group");
  ```

Elementary concepts of Input/Output:

Java I/O (Input and Output) is used *to process the input* and *produce the output*.

Java uses the concept of a stream to make I/O operation fast. The java.io package contains all the classes required for input and output operations.

We can perform **file handling in Java** by Java I/O API.

Byte Streams: -

Java byte streams are used to perform input and output of 8-bit bytes. Though there are many classes related to byte streams but the most frequently used classes are, FileInputStream and FileOutputStream. Following is an example which makes use of these two classes to copy an input file into an output file −

Example

```
import java.io.*;
public class CopyFile {

  public static void main(String args[]) throws IOException {
    FileInputStream in = null;
    FileOutputStream out = null;

    try {
      in = new FileInputStream("input.txt");
      out = new FileOutputStream("output.txt");
      int c;
      while ((c = in.read()) != -1) {
        out.write(c);
      }
    }finally {
      if (in != null) {
        in.close();
      }
      if (out != null) {
        out.close();
      }
    }
  }
}
```

As a next step, compile the above program and execute it, which will result in creating an output.txt file with the same content as we have in input.txt. So let's put the above code in CopyFile.java file and do the following −

```
$javac CopyFile.java
$java CopyFile
```

Character Streams

Java **Byte** streams are used to perform input and output of 8-bit bytes, whereas Java **Character** streams are used to perform input and output for 16-bit Unicode. Though there are many classes related to character streams but the most frequently used classes are, **FileReader** and **FileWriter.** Though internally FileReader uses FileInputStream and FileWriter uses FileOutputStream but here the major difference is that FileReader reads two bytes at a time and FileWriter writes two bytes at a time.

We can re-write the above example, which makes the use of these two classes to copy an input file (having Unicode characters) into an output file −

Example

```
import java.io.*;
public class CopyFile {

  public static void main(String args[]) throws IOException {
    FileReader in = null;
    FileWriter out = null;

    try {
      in = new FileReader("input.txt");
      out = new FileWriter("output.txt");
      int c;
      while ((c = in.read()) != -1) {
        out.write(c);
      }
    }finally {
      if (in != null) {
        in.close();
      }
      if (out != null) {
        out.close();
      }
    }
  }
}
```

As a next step, compile the above program and execute it, which will result in creating an output.txt file with the same content as we have in input.txt. So let's put the above code in CopyFile.java file and do the following −

```
$javac CopyFile.java
$java CopyFile
```

System.in: -

System.in is an InputStream which is typically connected to keyboard input of console programs. In other words, if you start a Java application from the command line, and you type something on the keyboard while the CLI console (or terminal) has focus, the keyboard input can typically be read via System.in from inside that Java application. However, it is only keyboard input directed to that Java application (the console / terminnal that started the application) which can be read via System.in. Keyboard input for other applications cannot be read via System.in .

System.in is not used as often since data is commonly passed to a command line Java application via command line arguments, files, or possibly via network connections if the application is designed for that. In applications with GUI the input to the application is given via the GUI. This is a separate input mechanism from System.in.

System.out: -

System.out is a PrintStream to which you can write characters. System.out normally outputs the data you write to it to the CLI console / terminal. System.out is often used from console-only programs like command line tools as a way to display the result of their execution to the user. This is also often used to print debug statements of from a program (though it may arguably not be the best way to get debug info out of a program).

System.err: -

System.err is a PrintStream. System.err works like System.out except it is normally only used to output error texts. Some programs (like Eclipse) will show the output to System.err in red text, to make it more obvious that it is error text.

Simple System.out + System.err Example:

Here is a simple example that uses System.out and System.err:

```
try {
  InputStream input = new FileInputStream("c:\\data\\...");
  System.out.println("File opened...");

} catch (IOException e){
  System.err.println("File opening failed:");
  e.printStackTrace();
}
```

Difference between print() and println()

As we know in Java these both methods are primarily used to display text from code to console. Both these methods are of PrintStream class and are called on static member 'out' of 'System' class which is a final type class.

The following are the important differences between print() and println().

Sr. No.	Key	print()	println()
1	Implementation	print method is implemented as it prints the text on the console and the cursor remains at the end of the text at the console.	On the other hand, println method is implemented as prints the text on the console and the cursor remains at the start of the next line at the console and the next printing takes place from next line.
2	Nature	The prints method simply print text on the console and does not add any new line.	While println adds new line after print text on console.
3	Arguments	print method works only with input parameter passed otherwise in case no argument is passed it throws syntax exception.	println method works both with and without parameter and do not throw any type of exception.

Example of print() vs println(): -

JavaTester.java

```
import java.io.*;
class JavaTester {
   public static void main(String[] args){
      System.out.print("Hello");
      System.out.print("World");
   }
}
```

Output: -

```
HelloWorld
```

The main difference between these two packages is that the read() and write() methods of Java IO are a blocking calls. By this we mean that the thread calling one of these methods will be blocked until the data has been read or written to the file.

On the other hand, in the case of NIO, the methods are non-blocking. This means that the calling threads can perform other tasks (like reading/writing data from another source or update the UI) while the read or write methods wait for their operation to complete. This can result in a significant performance increase if you're dealing with many IO requests or lots of data.

Examples of Reading and Writing Text Files: -

In the previous sections, we have discussed the different APIs provided by Java and now it's time to use these API classes in some code.

The example code below handles reading and writing text files using the various classes we detailed above. To simplify things, and provide a better comparison of the actual methods being used, the input and output are going to remain the same between the examples.

Note: To avoid any confusion on the file path, the example code will read and write from a file on in user's home directory. The user's home directory can be found using System.getProperty("user.home");, which is what we use in our examples.

Reading and Writing with FileReader and FileWriter

Let's start by using the `FileReader` and `FileWriter` classes:

```
String directory = System.getProperty("user.home");
String fileName = "sample.txt";
String absolutePath = directory + File.separator + fileName;

// Write the content in file
try(FileWriter fileWriter = new FileWriter(absolutePath)) {
    String fileContent = "This is a sample text.";
    fileWriter.write(fileContent);
    fileWriter.close();
} catch (IOException e) {
    // Exception handling
}

// Read the content from file
try(FileReader fileReader = new FileReader(absolutePath)) {
    int ch = fileReader.read();
    while(ch != -1) {
        System.out.print((char)ch);
        fileReader.close();
    }
} catch (FileNotFoundException e) {
    // Exception handling
} catch (IOException e) {
    // Exception handling
}
```

Both classes accept a String, representing the path to the file in their constructors. You can also pass a `File` object as well as a `FileDescriptor`.

The `write()` method writes a valid character sequence - either a `String`, a `char[]`. Additionally, it can write a single `char` represented as an `int`.