Error Handling

- Not all errors can be caught at compile time!
- Help -- run-time error! What next …?
- First ideas:
  - **`System.out.println()`**
  - **`System.err.println()`** (better than the first)
- Good guess but some errors call for corrective action, not just warning.
- In general, *printing* is a bad idea!
- Better: tell *someone* (not necessarily the user)!

Error Handling, cont.

- Establish return code convention
  - 0 vs. !0 in C/C++
  - **`boolean`** in Java

- Set value of a global variable
  - Done in many shells.
  - In Java use a public static field in a class.

- Raise an exception, catch it, and act
  - The idea comes from hardware.
  - Modern language support (Java, Python, Lisp, Ada, C++).

General Errors and Error Handling

- Error must be handled where the occur
  - One error in a method can be handled very differently in the clients, this is not a good approach. Repeating handling of the same error.
  - Can be extremely hard to debug.

- To handle an error detailed information on the error must be provided.
  - Where did the error occur (class, method, line number)
  - What type of error
  - A good error message
  - Dump of runtime stack? (too much information?)

- In object-oriented languages errors are represented by objects.

How to Handle Errors

- *Ignore*: False alarm just continue.
- *Report*: Write a message to the screen or to a log.
- *Terminate*: Stop the program execution.
- *Repair*: Make changes and try to recover the error.

- To be able to repair would be the best. However, often the best that can be done is the combination of report and terminate.

Java's Exception Handling

- *Exception*: An event that occurs during the execution of a program the disrupts the normal transaction flow.
  - A run-time phenomenon.

- Exception handling is part of the language.
- Exceptions are objects.
- Exceptions are structured in a class hierarchy.
- It is not possible to ignore an exceptions (very nice feature).
  - A method defines which exception may occur, the client must anticipate these exceptions, otherwise compile-time error.
- It is sometimes possible to recover to a known good state after an exception was raised.

Java's Exception Handling, cont.

- Java’s object-oriented way to handle errors
  - more powerful, more flexible than using return
  - keywords **`try`**, **`catch`**, **`throw`**, **`throws`**, **`finally.`**
- An *exception* is an object that describes an erroneous or unusual situation.
- Exceptions are *thrown* by a program, and may be *caught* and *handled* by another part of the program.
- A program can therefore be separated into a normal execution flow and an *exception execution flow*.
- An *error* is also represented as an object in Java, but usually represents a unrecoverable situation and should not be caught.

Motivation for Exception 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;
```

```
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;
    }
}
```

[source: java.sun.com]

Exception Handling Model

- Code where you anticipate a problem:
  - detect error, probably with an if create a new exception and **`throw`** it
  - or let JVM detect error, create and throw an exception

```
public static void main (String args[]) throws
        exception1, exception2, exception3 {
    . . .
}
```

Code in client (somewhere in message invocation stack)

- **`try`**, hoping for the best
- prepare to **`catch`** an exception

```
try {
    // statements that can throws exceptions...
} catch ( exception1 ) {
    // do stuff
} catch ( exception2 ) {
    // do stuff
}
```

Java's Catch or Specify Requirement

- Catch
  - A method can catch exception by providing and exception handler.
- Specify
  - If a method chooses not to catch, then specify which exceptions are thrown.
  - Exceptions are part of a method's public interface.

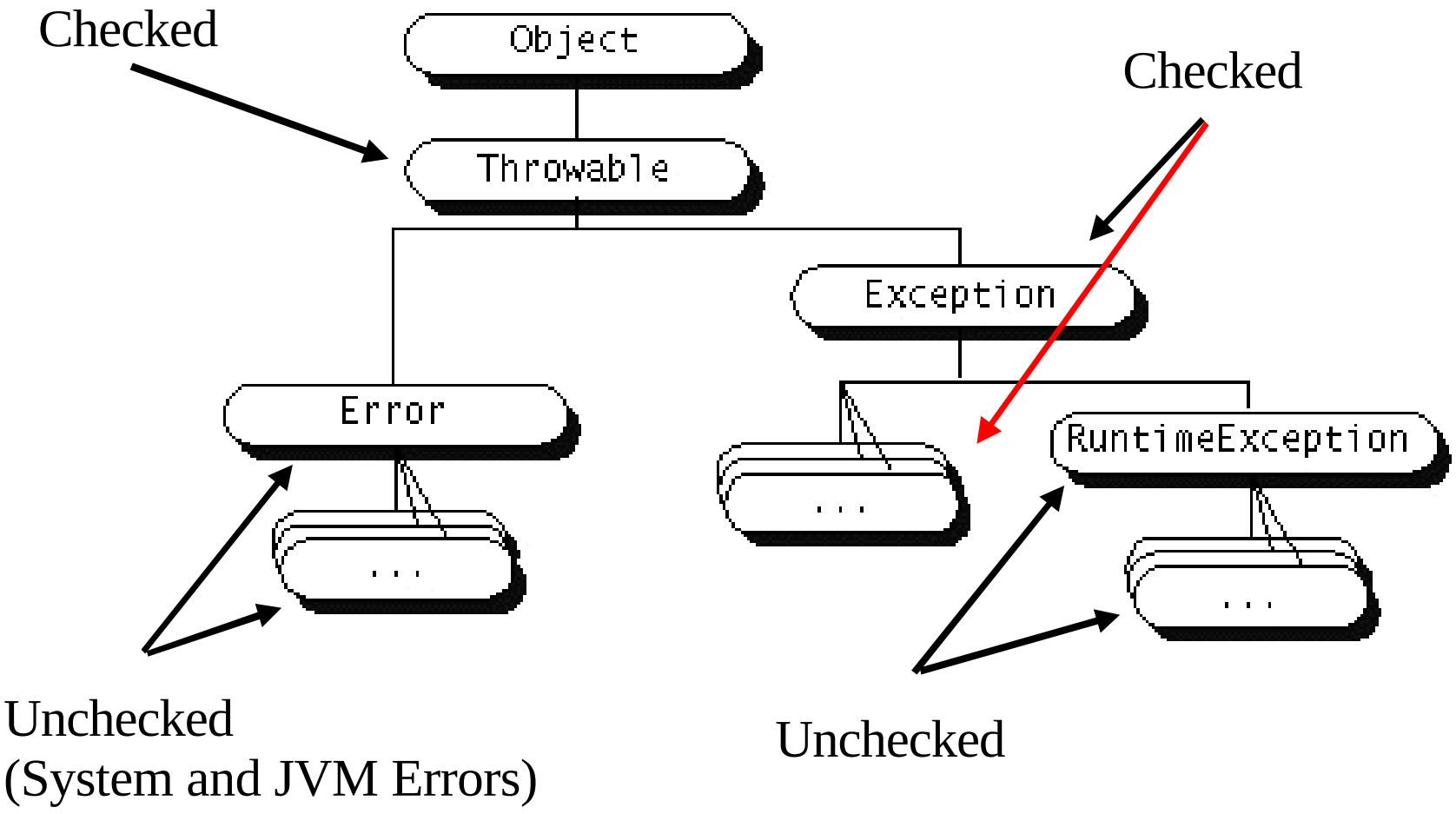
Checked/Unchecked Exceptions

- An exception is either *checked* or *unchecked*
  - Checked = checked by the compiler

- A *checked exception* can only be thrown within a try block or within a method that is designated to throw that exception.
  - The compiler will complain if a checked exception is not handled appropriately.

- An *unchecked exception* does not require explicit handling, though it could be processed that way.
  - An an example many run-time exceptions are unchecked exceptions.

Exception Class Hierarchy



Exception Hierarchy, cont.

- **`Throwable`**
  - Superclass for all exceptions
  - Two methods for filling in and printing the stack
- **`Error`**
  - Serious internal errors (should not occur in running programs).
  - Are normally not handled. (report and terminate)
  - Programs should not throw **`Error`**
  - The catch or specify principle does not apply, because they are so severe.
  - Examples
    - Dynamic linking failure
    - Memory shortage
    - Instantiating abstract class

Exception Hierarchy, cont.

- **`RuntimeException`**
  - Not a good name (all exceptions are at run-time)!
  - Commonly seen run-time error
  - The catch or specify principle does not apply, because they are so ubiquitous.
  - Examples
    - Divide by zero/Cast error/Null pointer
- **`IOException`**
  - Related to input and output
  - The catch or specify principle does apply
  - Examples
    - File does not exist
    - End of file

The `try` Statement

- To process an exception when it occurs, the line that throws the exception is executed within a *try block*.
- A try block is followed by one or more *catch* clauses, which contain code to process an exception.
- Each catch clause has an associated exception type.

```
try {
   // statements
}
```

The `catch` Statement

- The catch statement is used for catching exceptions.
- A try statement must be accompanied by a catch statement.
- Try and catch statements can be nested, i.e., try block in try block, etc.

```
try {
    . . .
} catch (ArrayIndexOutOfBoundsException e) {
    System.err.println("Caught first " + e.getMessage());
} catch (IOException e) {
    System.err.println("Caught second " + e.getMessage());
}
```

The `catch` Statement, cont.

- When an exception occurs, processing continues at the first catch clause that matches the exception type.
- The catch statements should be should be listed in *most-specialized-exception-first* order.

```
try {
    . . .
} catch (Exception e) { // very general exception
    System.err.println("Caught first " + e.getMessage());
}

 catch (ArrayIndexOutOfBoundsException e) {
    // will never be called
    System.err.println("Caught second " + e.getMessage());
}
```

The `finally` Clause

- A try statement can have an optional clause designated by the reserved word **`finally`**.
- If no exception is generated, the statements in the finally clause are executed after the statements in the **`try`** block complete.
- Also, if an exception is generated, the statements in the finally clause are executed after the statements in the appropriate catch clause complete.

```
try {
      // statements that throw exceptions
} catch( <exception>) {
      // do stuff
} finally {
      // code here runs whether or not catch runs
}
```

The `finally` Clause, Example

```
try {
   out = new PrintWriter(new FileWriter("out.txt"));
   // statements that throws exceptions

    } catch (ArrayIndexOutOfBoundsException e) {
        System.err.println("Caught array error");
    } catch (IOException e) {
        System.err.println("Caught I/O error");
    } finally {
        if (out != null) {
            System.out.println("Closing file);
            out.close();
        }
    }
}
```

The **`throw`** Statement

- All Java methods use the **`throw`** statement to throw an exception.

```
public Object pop() throws EmptyStackException {
    Object obj;

    if (size == 0)
        throw new EmptyStackException();

    obj = objectAt(size – 1);
    setObjectAt(size - 1, null);
    size--;
    return obj;
}
```

[source: java.sun.com]

Exception Propagation

- If it is not appropriate to handle the exception where it occurs, it can be handled at a higher level.
- Exceptions *propagate* up through the method calling hierarchy until they are caught and handled or until they reach the outermost level.
- A try block that contains a call to a method in which an exception is thrown can be used to catch that exception.

Exception Propagation, Example

```
void method1 throws IOException {
    throw new IOException("Error in method1");
}

void method2 throws IOException {
    // do stuff, but no catch, just specify
    method1();
}
void method3 throws IOException {
    // do stuff, but no catch, just specify
    method2();
}

public static void main (String args[]){
   // catch if just specify error to console
   try {
      method3();
   } catch (IOException e){
      // handle the exception from method1
   }
}
```

Rethrowing an Exception

```
void method1 throws IOException {
    throw new IOException("Error in method1");
}

void method2 throws IOException {
    try{
        method1();
    } catch (IOException e) {
        System.out.printly ("Handle partly here");
        throw e; // 1st method
        // throw e.fillInStackTrace;          // 2nd method
        // throw new IOException ("new one"); // 3th method
    }
}

public static void main (String args[]){
   // catch if just specify error to console
   try {
      method2();
   } catch (IOException e){
      System.out.printly ("Handle rest here");
   }
}
```

Creating New Exceptions

- Requires careful design (part of the public interface).
- Can an existing **`Exception`** be used?
- Choose the correct superclass.
- Choosing the name
  - The most important thing for new exceptions.
  - Tends to be long an descriptive (ArrayIndexOutOfBoundsException)
- Code for exception class typically minimal

- Naming convention:
  - All classes that inherits from **`Exception`** has 'Exception' postfixed to their name.
  - All classes that inherits from **`Error`** has 'Error' postfixed to their name.

Creating New Exceptions, Example

```
class SimplestException extends Exception {
    // empty method body, give it a good name
}

class SimpleException extends Exception {
    SimpleException () { super(); } // default constructor
    SimpleException (String str) { super(str); }
}

class ExtendedException extends Exception {
    private static int counter = 0;
    private int instanceNo = 0;
    ExtendedException () { super(); counter++; }
    ExtendedException (String str) {
        super(str); counter++;   }
    ExtendedException (String str, int no) {
        instanceNo = no;
        counter++;
        super(str);
    }
}
```

Inheritance and Exceptions

- If base-class method throws an exception, derived-class method may throw that exception or one derived from it.

- Derived-class method cannot throw an exception that is not a type/subtype of an exception thrown by the base-class method.

Guidelines

- Do not use exceptions for normal control flow!
- Do use exceptions to indicate abnormal conditions!

- Handle the error (fully or partially) if you have enough information in the current context. Otherwise, propagate!
- Handle group of statements
  - Do not encompass every single statement in a try block
- Use exceptions in constructors!
- Do something with the exceptions your code catches!
- Clean up using finally.

Summary

- The manner in which an exception is processed is an important design consideration.

- Advantages of Exceptions
  - Separates error handling from "regular" code.
  - Propagation of errors up the call stack.
    - Handle error in a context
  - Grouping of error type and differentiation of errors.
    - Overview
    - Reuse of error handling code