

CMSC 132:

OBJECT-ORIENTED PROGRAMMING II



Program Correctness

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Announcements

- We update slides/example often. Always get class material from the web site

Overview

- Program correctness is determined by the presence / absence of **program defects** (errors)
- Issues
 - Types of program errors
 - Compile-time
 - Run-time
 - Logic
 - Testing
 - Debugging
 - Exceptions

Program Errors (Compile-Time)

- Errors in code construction
 - Lexical (typographical), grammatical, types
- Detected during compilation
- Usually easy to correct quickly
- Examples
 - Misspelled keyword
 - Missing or misplaced symbol
 - Incorrect operator for variable type

Program Errors (Run-time)

- Operations illegal / impossible to execute
- Detected during program execution
 - But not detectable at compile time
- Treated as **exceptions** in Java
- Examples
 - Division by zero
 - Array index out of bounds
 - Using null pointer
 - Illegal format conversion

Program Errors (Logic)

- Logic errors
 - Operations leading to incorrect program state
 - May (or may not) lead to run-time errors
 - Problem in design or implementation of algorithm
- Examples
 - Computing incorrect arithmetic value
 - Ignoring illegal input (GIGO)
- Hardest error to handle
 - Detect by **testing**
 - Fix by **debugging**

Testing

- Run program (or part of program) under controlled conditions to verify behavior
 - Detects **run-time error** if exception thrown
 - Detects **logic error** if behavior is incorrect
 - Use of debugger is extremely important
- Issues
 - Selecting test cases
 - Think of them as you develop code or before
 - Testing different parts of program
 - Test coverage
 - Others

Test Coverage

- Whether code is executed by **some** test case
- Automatically calculated by submit server
 - For set of tests selected (from link)
 - E.g., student tests, public tests, student+public tests
 - For conditionals, reports X/Y where
 - X = # tests executing True
 - Y = # tests executing False
 - Color
 - Green = executed by some test case
 - Pink = not executed
- In the submit server you can find results by selecting “view source” in “Submissions” report

Test Coverage Example

Source Code

Coverage information for public test #all:

Source file	statements	conditionals	methods	total
Utilities.java	4/10	1/5	1/2	

```
1      package utilities;
2
3      public class Utilities {
4          2      public static String letterGrade(double numericGrade) {
5              1/1          if (numericGrade >= 90.0)
6                  1              return "A";
7              1/0          else if (numericGrade >= 80.0)
8                  1              return "B";
9              0/0          else if (numericGrade >= 70.0)
10                 0              return "C";
11                 0/0          else if (numericGrade >= 60.0)
12                     0              return "D";
13                 else
14                     0              return "F";
15             }
16
17             0      public static boolean passingNumericGrade(double numericGrade) {
18                 0/0          return numericGrade >= 70.0 ? true : false;
19             }
20     }
```

Exceptions (Rare Events)

- Rare event outside normal behavior of code
 - Usually a **run-time error**
- Examples
 - Division by zero
 - Access past end of array
 - Out of memory
 - Number input in wrong format (float vs. integer)
 - Unable to write output to file
 - Missing input file

Dealing with Exceptions

- What to do when an exception occurs?
 - Ignore the problem
 - Print error message
 - Request data
 - Exit program
 - Exit method returning error code that caller must check.
- Problems:
 - Calling method may forgot to check code
 - Agreement on error codes
 - Error handling code mixed with normal code
- Use **Exception Handling** (e.g., Java's exception mechanism)
 - Preferred!

Exception Handling Advantages

- Compiler ensures exceptions are caught eventually
- No need to explicitly **propagate** exception to caller
 - **Backtrack** to caller(s) automatically
- Class hierarchy defines meaning of exceptions
 - No need for separate definition of error codes
- Exception handling code separate & clearly marked

Representing Exceptions in Java

- Exceptions represented as
 - Objects derived from class Throwable
- Code

```
public class Throwable extends Object {  
    Throwable()                // No error message  
    Throwable(String msg)      // Error message  
    String getMessage()        // Return error msg  
    void printStackTrace( ) { ... } // Record methods  
    ...                        // called & location  
}
```

Java Exceptions

- Any code that can potentially throw an exception is enclosed in a
 - **try { } block**
- Exception handlers are specified using catch
 - **catch(ExceptionType e) { }**
- You can have several catch clauses associated with a try block
- When an exception is thrown
 - Control exits the try block
 - Proceeds to closest matching exception handler after the try block
 - Java Exceptions backtracks to caller(s) until matching catch block found
 - Execute code in exception handler
 - Execute code in finally block (if present)
- Example: Fundamentals.java
- Scope of try is dynamic
 - Includes code executed by methods invoked in try block (and their descendents)

Java Exceptions

- **Throwing exceptions**

- In previous example the exception was thrown for you
- You can throw exceptions too
 - throw <Object of class exception>
- Example:
throw new UnsupportedOperationException("You must implement this method.");

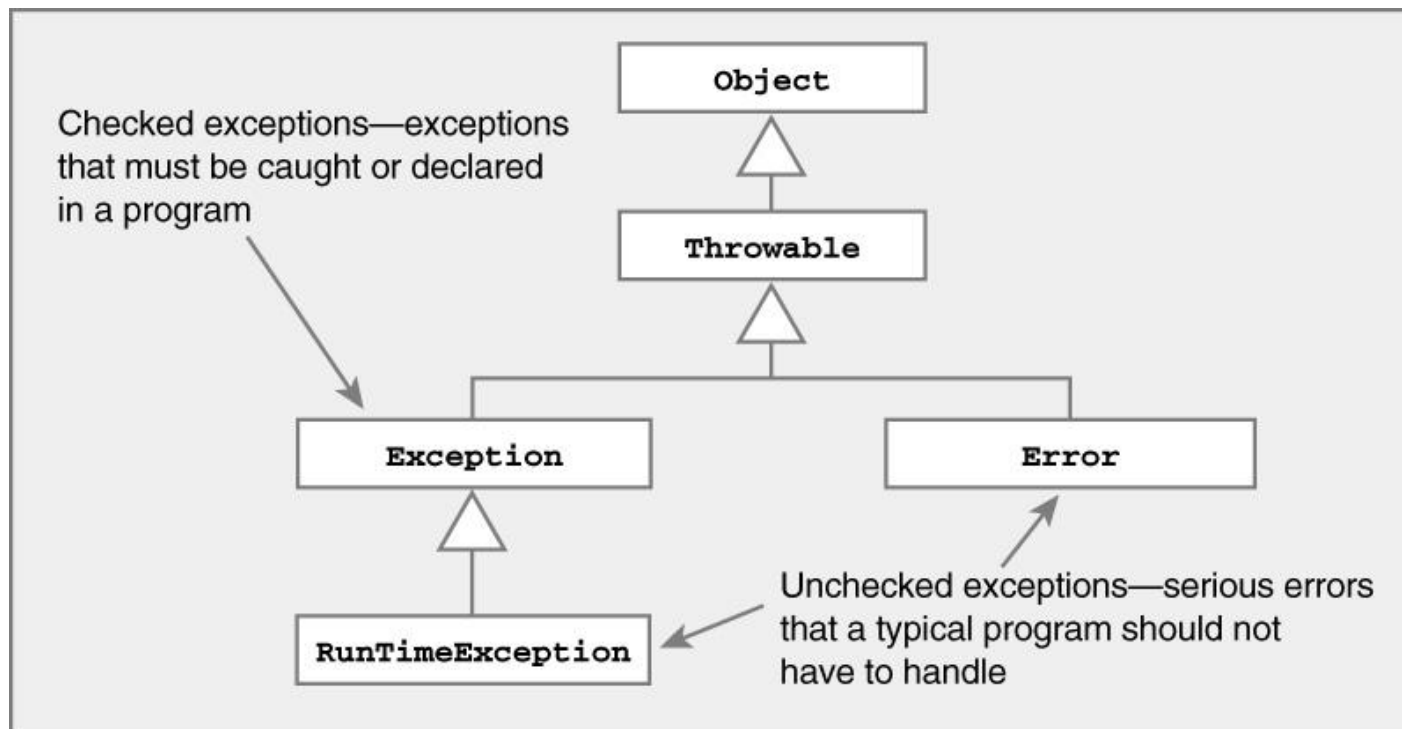
- **Finally block**

- Code that is executed no matter what
 - Regardless of which catch block
 - Even if no catch block is executed
 - Executed before transferring control to caller
- Placed after try and all catch blocks
- Tries to restore program state to be consistent, legal (e.g., closing files)

- **Example:** Finally.java

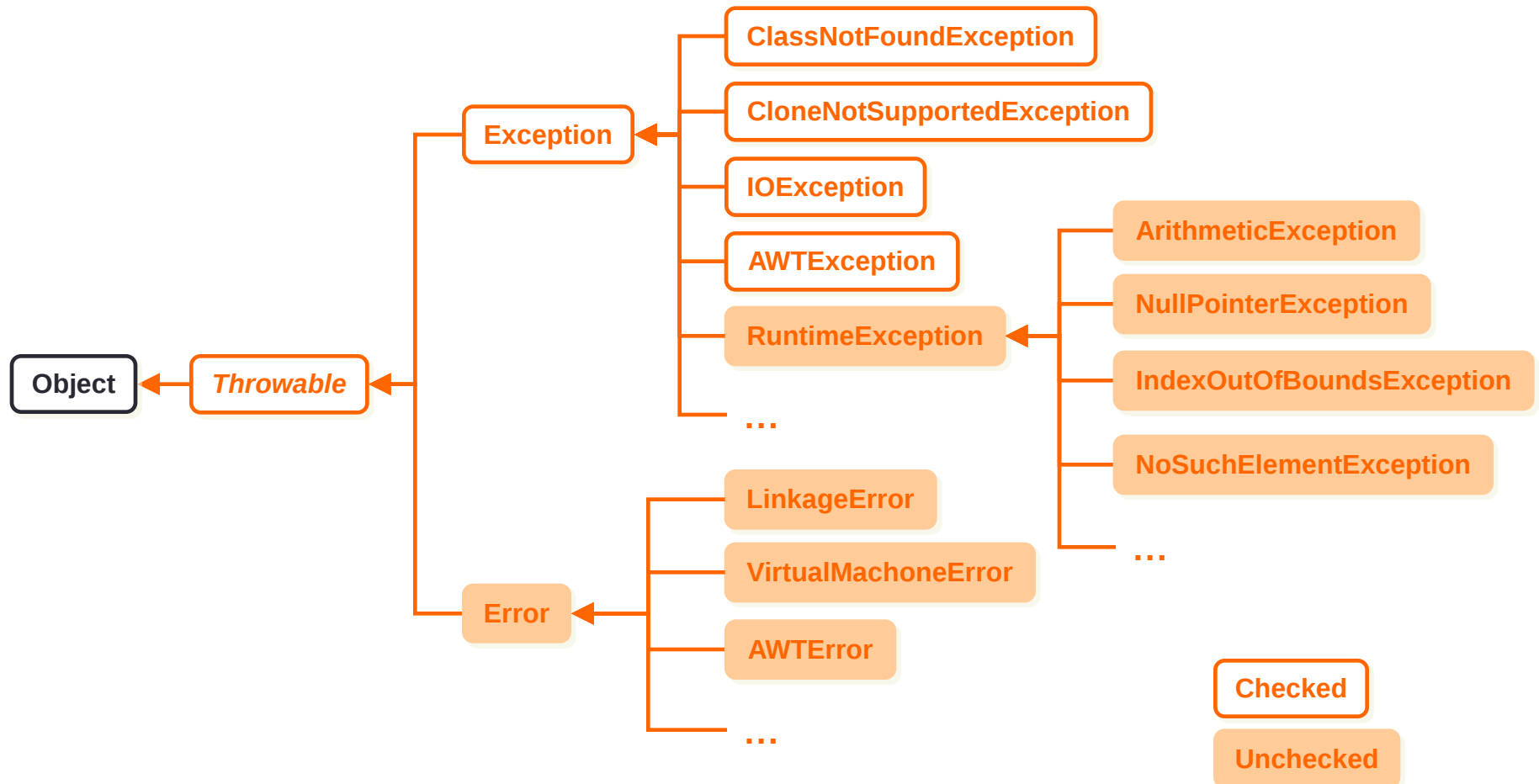
Representing Exceptions

- Java Exception class hierarchy
 - Two types of exceptions $\Rightarrow$ **checked & unchecked**



Representing Exceptions

- Java Exception class hierarchy



Checked and Unchecked Exceptions

- **Unchecked**

- Serious errors not handled by typical program
- Usually indicate logic errors
- Examples → NullPointerException, IndexOutOfBoundsException
- Catching unchecked exceptions is **optional** (handled by JVM if not caught)

- **Checked**

- Errors typical program should handle
- Used for operations prone to error
- Examples → IOException, ClassNotFoundException
- Compiler requires “**catch or declare**”
 - Catch and handle exception in method, OR
 - Declare method can throw exception, forcing calling function to catch or declare exception in turn
- **Example:** Caught.java, Declared.java

Miscellaneous

- Use exceptions only for rare events
 - Not for common cases (e.g., checking end of loop)
 - High overhead to perform catch
- Use existing Java Exceptions if possible
- **Avoid simply catching & ignoring exceptions**
 - `catch (Exception e) { } // Nothing in between { }`
 - Poor software development style
- An exception can be rethrown

```
catch (ExceptionType e) {  
    throw e;  
}
```