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
- Remember that you can work at school computers. See additional information at:
  - http://www.cs.umd.edu/eclipse/launch.html#campus
- Submit your project often so you have a copy in the submit server
  - If something happens you have a back up (in addition to the one CVS provides)
- Regarding documentation for projects
- Regarding office hours the day the project is due
- Regarding tokens for a particular project
  - Check the submit server to find out how many tokens you have for a particular project
- We cannot provide any information regarding release, secret tests (not even hints)

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

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
  - 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
- Eclipse Coverage Tool http://www.eclemma.org/index.html

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        }
```

About Testing

- **JUnit**
  - Review the information available at http://www.cs.umd.edu/eclipse/JUnitTesting.html
  - Notice the problem you may experience while using static and Junit
- **Submit Server**
  - In addition to coverage information, the submit server provides feedback (warnings, etc.) regarding your code. Don't ignore them.
- **Findbugs (Static Analysis to find coding mistakes)**
  - http://findbugs.sourceforge.net/

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 (Rare Events)

- What to do when this kind of event occurs?
  - Ignore the problem
  - Print error message
  - Request data
  - Exit method returning error code caller must check
  - Exit program
- Exiting method returning error code has disadvantages
  - Calling method may forget to check code
  - Agreement on error codes
  - Error handling code mixed with normal code
- Preferred approach: **Exception Handling** (e.g., Java's exception mechanism)

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  {
    Throwable()              // No error message
    Throwable(String mesg)      // Error message
    String getMessage()      // Return error mesg
    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

Java Exceptions

- 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

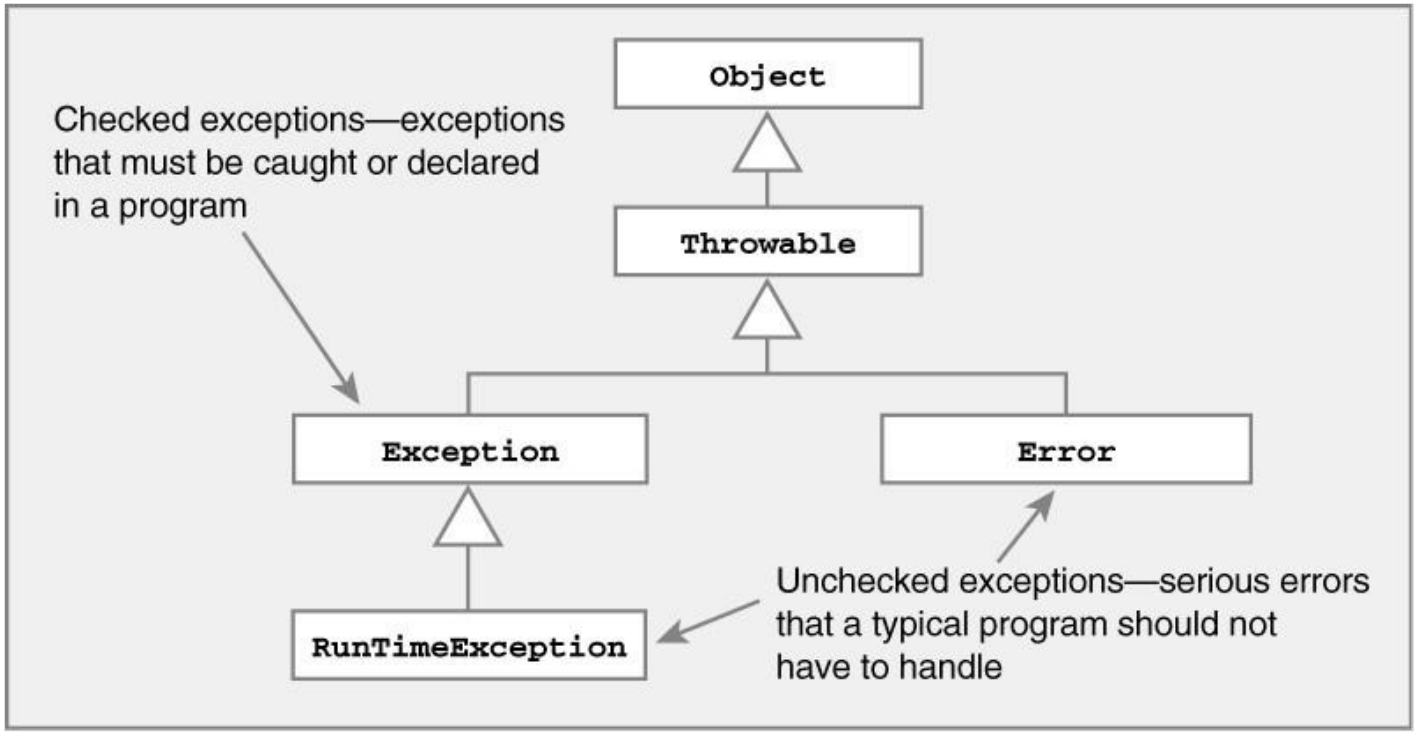
- **Throwing exceptions**
  - In previous example the exception was thrown for you
  - You can throw exceptions too
    - throw <Object of class exception>
  - Example:

```
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:** ReadNegativeValue.java

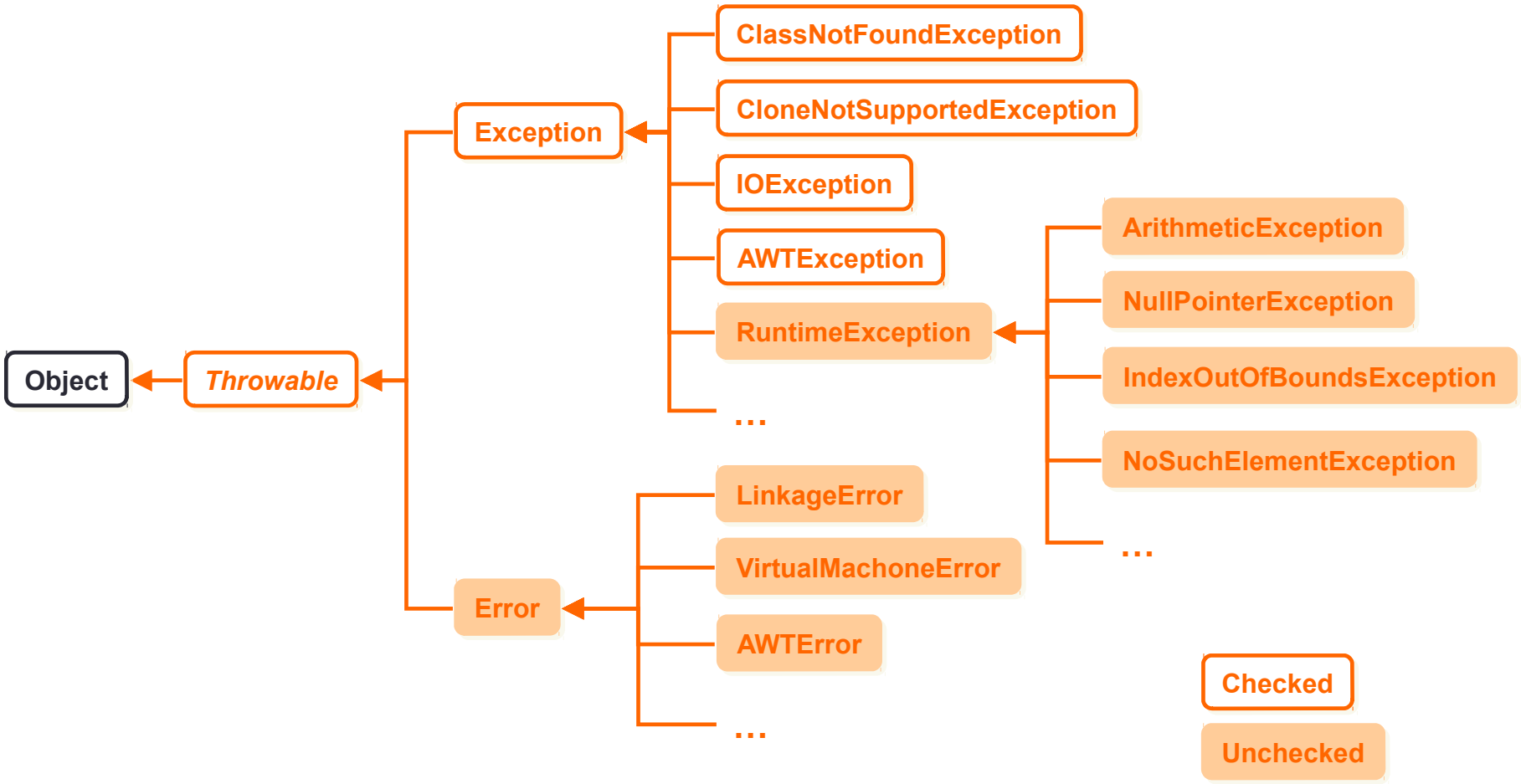
Representing Exceptions

- Java Exception class hierarchy
  - Two types of exceptions ⇒ checked & unchecked



Representing Exceptions

- Java Exception class hierarchy



Checked and Uncheck Exceptions

- **Unchecked**
  - Serious errors not handled by typical program
  - They are your fault (your code is wrong)
  - Usually indicate logic errors
  - Examples NullPointerException, IndexOutOfBoundsException
  - Catching unchecked exceptions is optional (handled by JVM if not caught)
- **Checked**
  - Errors typical program should handle. Describes problem that may occur at times, regardless how careful you are
  - 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;
}
```

  - **Example:** ReadNegativeValueRethrow.java