Exceptions

Errors and Exceptions

- An error is a bug in your program
  - dividing by zero
  - going outside the bounds of an array
  - trying to use a null reference
- An exception is a problem whose cause is outside your program
  - trying to open a file that isn’t there
  - running out of memory

What to do about errors and exceptions

- An error is a bug in your program
  - It should be *fixed*
- An exception is a problem that your program may encounter
  - The source of the problem is outside your program
  - An exception is not the "normal" case, *but*...
  - ...your program must be prepared to deal with it
- This is not a formal distinction–it isn't always clear whether something should be an error or an exception

Dealing with exceptions

- Most exceptions arise when you are handling files
  - A needed file may be missing
  - You may not have permission to write a file
  - A file may be the wrong type
- Exceptions may also arise when you use someone else's classes (or they use yours)
  - You might use a class incorrectly
  - Incorrect use should result in an exception

The problem with exceptions

- Here's what you might *like* to do:
  - *open a file*
  - *read a line from the file*
- But here's what you might *have* to do:
  - *open a file*
  - *if the file doesn't exist, inform the user*
  - *if you don't have permission to use the file, inform the user*
  - *if the file isn't a text file, inform the user*
  - *read a line from the file*
  - *if you couldn't read a line, inform the user*
  - *etc., etc.*
- All this error checking really gets in the way of understanding the code

Three approaches to error checking

- **Ignore all but the most important errors**
  - The code is cleaner, but the program will misbehave when it encounters an unusual error

- **Do something appropriate for every error**
  - The code is cluttered, but the program works better
  - You might still forget some error conditions

- **Do the normal processing in one place, handle the errors in another (this is the Java way)**
  - The code is at least reasonably uncluttered
  - Java tries to ensure that you handle every error

The try statement

- Java provides a new control structure, the try statement (also called the try-catch statement) to separate "normal" code from error handling:

```
try {
    do the "normal" code, ignoring possible exceptions
}
catch (some exception) {
    handle the exception
}
catch (some other exception) {
    handle the exception
}
```

Exception handling is *not* optional

- As in other languages, *errors* usually just cause your program to crash
- Other languages leave it up to you whether you want to handle *exceptions*
  - There are a lot of sloppy programs in the world
  - It’s normal for human beings to be lazy
- Java tries to *force* you to handle exceptions
  - This is sometimes a pain in the neck, *but*...
  - the result is almost always a better program

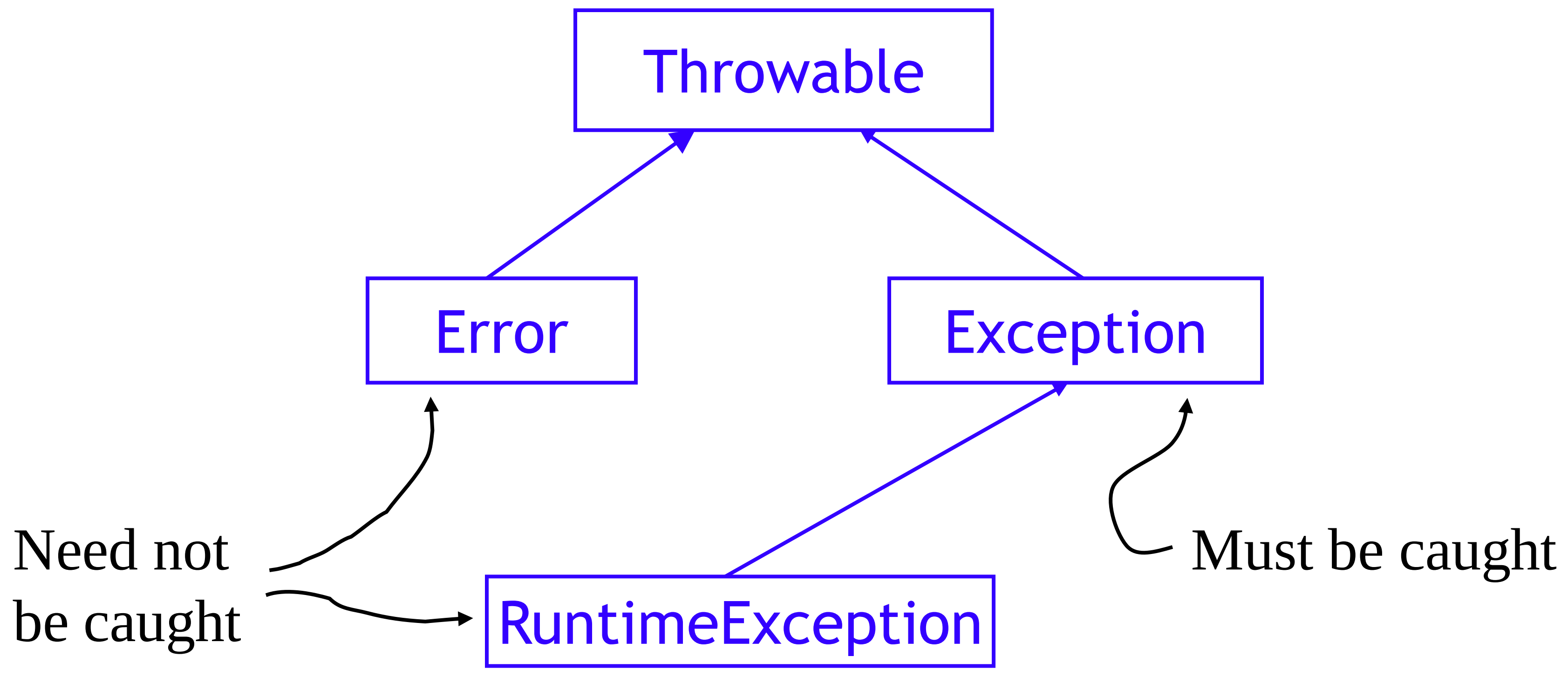
Error and Exception are Objects

- In Java, an error doesn't *necessarily* cause your program to crash
- When an *error* occurs, Java throws an Error object for you to use
  - You can catch this object to try to recover
  - You can *ignore* the error (the program will crash)
- When an *exception* occurs, Java throws an Exception object for you to use
  - You **cannot ignore** an Exception; you must catch it
  - You get a *syntax error* if you forget to take care of any possible Exception

The exception hierarchy

- Throwable: the superclass of “throwable” objects
  - Error: Usually should not be caught (instead, the bug that caused it should be fixed)
  - Exception: A problem that must be caught
    - RuntimeException: A special subclass of Exception that does *not* need to be caught
- Hence, it is the Exceptions that are most important to us (since we have to do something about them)

The Exception hierarchy II



A few kinds of Exceptions

- IOException: a problem doing input/output
  - FileNotFoundException: no such file
  - EOFException: tried to read past the <u>E</u>nd <u>O</u>f <u>F</u>ile
- NullPointerException: tried to use a object that was actually null (this is a RuntimeException)
- NumberFormatException: tried to convert a non-numeric String to a number (this is a RuntimeException)
- OutOfMemoryError: the program has used all available memory (this is an Error)
- There are about 200 predefined Exception types

What to do about Exceptions

- You have two choices:
  - You can "catch" the exception and deal with it
    - For Java's exceptions, this is usually the better choice
  - You can "pass the buck" and let some other part of the program deal with it
    - This is often better for exceptions that you create and throw
- Exceptions should be handled by the part of the program that is best equipped to do the right thing about them

What to do about Exceptions II

- You can catch exceptions with a `try` statement
  - When you catch an exception, you can try to repair the problem, or you can just print out information about what happened
- You can "pass the buck" by stating that the method in which the exception occurs "throws" the exception
  - Example:

```
void openFile(String fileName) throws IOException { ... }
```

- Which of these you do depends on *whose responsibility it is* to do something about the exception
  - If the method "knows" what to do, it should do it
  - If it should really be up to the user (the method caller) to decide what to do, then "pass the buck"

How to use the try statement

- Put try {…} around any code that *might* throw an exception
  - This is a *syntax* requirement you cannot ignore
- For each Exception object that might be thrown, you must provide a catch phrase:

  catch (***exception_type name***) {…}

  - You can have as many catch phrases as you need
  - *name* is a formal parameter that holds the exception object
  - You can send messages to this object and access its fields

finally

- After all the catch phrases, you can have an *optional* finally phrase
- try { … }
  catch (AnExceptionType *e*) { … }
  catch (AnotherExceptionType *e*) { … }
  finally { … }
- Whatever happens in try and catch, *even if it does a return statement*, the finally code will be executed
  - If no exception occurs, the finally will be executed after the try code
  - In an exception does occur, the finally will be executed after the appropriate catch code

How the `try` statement works

- The code in the `try {…}` part is executed
- If there are no problems, the `catch` phrases are skipped
- If an exception occurs, the program jumps *immediately* to the first `catch` clause that can handle that exception
- Whether or not an exception occurred, the `finally` code is executed

Ordering the catch phrases

- A try can be followed by many catches
  - The first one that *can* catch the exception is the one that *will* catch the exception
- Bad:

```
catch(Exception e) { . . . }
catch(IOException e) { . . . }
```

- This is bad because IOException is a subclass of Exception, so any IOException will be handled by the *first* catch
  - The second catch phrase can never be used

Using the exception

- When you say catch(IOException e), e is a *formal parameter* of type IOException
  - A catch phrase is almost like a miniature method
  - e is an instance (object) of class IOException
  - Exception objects have methods you can use
- Here's an especially useful method that is defined for every exception type:

```
e.printStackTrace();
```

  - This prints out what the exception was, and how you got to the statement that caused it

printStackTrace()

- printStackTrace() does *not* print on System.out, but on another stream, System.err
  - Eclipse writes this to the same Console window, but writes it in red
  - From the command line: both System.out and System.err are sent to the terminal window
- printStackTrace(***stream***) prints on the given stream
  - printStackTrace(System.out) prints on System.out, and this output is printed along with the "normal" output

Throwing an Exception

- If your method uses code that might throw an exception, and you don’t want to handle the exception in this method, you can say that the method “throws” the exception
- Example:

```
String myGetLine( ) throws IOException { ... }
```

- If you do this, then the method that calls this method must handle the exception

Constructing an Exception

- Exceptions are classes; you can create your own Exception with new
  - Exception types have two constructors: one with no parameters, and one with a String parameter
- You can subclass Exception to create your own exception type
  - But first, you should look through the predefined exceptions to see if there is already one that's appropriate

Throwing an Exception

- Once you create an Exception, you can throw it
  - `throw new UserException("Bad data");`
- You don't *have* to throw an `Exception`; here's another thing you can do with one:
  - `new UserException("Bad data").printStackTrace();`

Why create an Exception?

- If you are writing methods for someone else to use, you want to do something reasonable if they use your methods incorrectly
- Just doing the wrong thing isn't very friendly
- Remember, error messages are a good thing—much better than not having a clue what went wrong
  - Exceptions are even better than error messages, because they allow the user of your class to decide what to do

Review: the assert statement

- The purpose of the assert statement is to document something you believe to be true
- There are two forms of the assert statement:
  - assert ***booleanExpression***;
  - assert ***booleanExpression*** : ***expression***;
- By default, Java has assertions *disabled*—that is, it *ignores* them
  - To change this default
    - Open Window → Preferences → Java → Installed JREs
    - Select the JRE you are using (should be 1.6.*something*)
    - Click Edit…
    - For Default VM Arguments, enter -ea (enable assertions)
    - Click OK (twice) to finish

Assertions or Exceptions?

- **Exceptions**
  - Are used to catch error conditions "from outside," such trying to read a file that doesn't exist
  - Can also be used to check parameters, or the state of an object, to warn users of your class that they have done something wrong
- The `assert` statement
  - Is used as "live" documentation, to specify something that you believe will always be true
  - If you can think of circumstances where it won't be true, you should *not* be using `assert`
  - But because assert is easier than Exceptions, it can sometimes be used for error checking in your own `private` methods
- Philosophy: You have to get your own class correct; you can't expect other classes to be correct
  - Assertions are "internal;" Exceptions are "external"

The End

As soon as we started programming, we found to our surprise that it wasn't as easy to get programs right as we had thought. Debugging had to be discovered. I can remember the exact instant when I realized that a large part of my life from then on was going to be spent in finding mistakes in my own programs.

— Maurice Wilkes discovers debugging, 1949