Object – Oriented Design with UML and Java

Part VI: Exception Handling in Java

Version 2023

Exception Handling

- A false sense of security?
- Care must be taken if you intend for the program to continue running.
- Both C++ and Java support exceptions.
- Normal control flow (looping, etc.) and recursion are relatively easy to get right; Multi-threaded control flow is very difficult; Exception Handling looks easy, but it takes planning and effort to get right.
- Design you Exception Handling as part of a larger error logging, monitoring, diagnostics, and recovery infrastructure.
- Try to avoid throwing exceptions yourself, in most cases.
- Consider every plausible failure scenario.
- Is your system required to return meaningful error messages?
- Consider your system's ***resilience*** in the larger context. This is a hard problem that is out of scope for this course.

The Basic E.H. Model

- Java and C++ have subtle differences in their exception handling, but here, in the abstract, is what the two approaches have in common…

```
try {
   throw new Exception( “Error!” );
   // Skip over this code
}
catch( Exception e ) {
  // Do something about the Exception...
}
```

The **throw** statement is like a *goto*; it jumps to the nearest matching **catch** without executing any intervening code, with the following exceptions:

- In Java, any code within an intervening **finally** block will get executed.
- C++ objects in stack memory will get destructed when they go out of scope. Note: do not throw an exception from a C++ destructor!

C++ Example

- Suppose a class **DatabaseException** is a subclass of **Exception**...

```
try
{
  throw new DatabaseException( “Deadlock detected!” );
  cout << “The impossible has happened!” << endl;
}
catch( Exception* e ) // Nearest matching catch.
{
  cout << “Exception caught. ” << endl;
}
```

- *Outputs:* **Exception caught.**

Java's Checked Exceptions

The C++ language allows anything to be thrown.

Java only allows throwing subclasses of `java.lang.Throwable`.

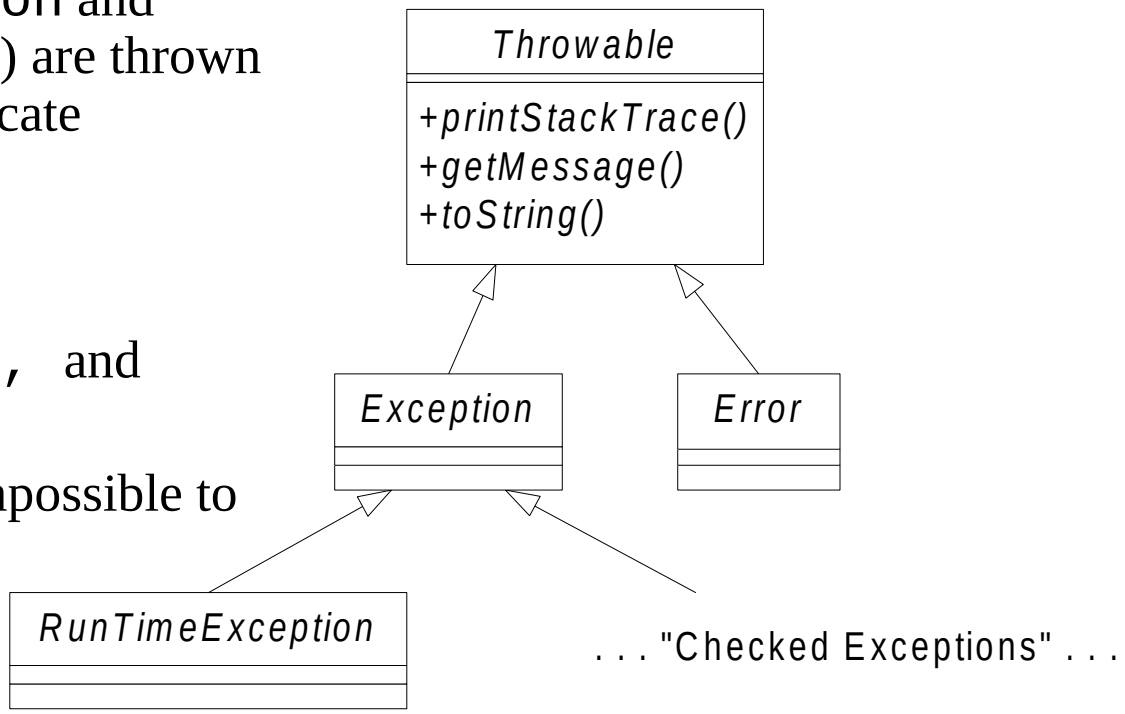
- Java provides Compile-Time Support for "checked" exceptions:
- ***Checked Exceptions*** are subclasses of `java.lang.Exception`, excluding subclasses of `RuntimeException`.
- If there is a chance that a checked exception might get thrown from a given method, that method ***must*** either catch it, or declare it with a throws clause:

```
public void myMethod() throws FooException {
  throw new FooException();
}
```

Java's Exception Hierarchy

Unchecked exceptions include subclasses of `Error` and `RuntimeException`.

- `RuntimeExceptions` (such as `NullPointerException` and `ClassCastException`) are thrown by the Java runtime to indicate programming errors.
- `Errors` include: `OutOfMemoryError`, `StackOverflowError,` and `ThreadDeath, ...`
- `Errors` are difficult or impossible to recover from.



Catching Everything

```
try {
  throw new DatabaseException( “Deadlock detected!” );
}
catch( DatabaseException dbe ) {
  retryAfterDeadlock();
}
catch( Throwable t ) // Beware of Errors.
{
  log.Error( “Unexpected Problem!” + t ); // see Log4j
}
```

- C++ also provides a way to catch all possible exceptions:

```
catch( … ) {}
```

A More Realistic Example

```
try {
  dbConnection.beginTransaction();
  boolean result = doTransaction( dbConnection, info );
  dbConnection.commitTransaction();
  return result;
}
catch( Throwable t ) { // Better: catch expected exceptions
  dbConnection.rollbackTransaction();
  Log.log( "Transaction rolled back!", Severity.ERROR, t );
  return false;
}
finally { // This code gets executed no matter what.
  dbConnection.close(); // Frees system resources.
}
```

Exception Handling

It is not easy to write robust code in the presence of exceptions.

- Ensure that every function leaves its object in such a state that its destructor (C++) may be called, whenever any exception gets thrown.
- It is desirable, but sometimes very difficult, to ensure that if an exception gets thrown, the object is in the same state it was in before the function ever got called.
- At a minimum, make sure the object remains in a consistent state!

Note that in C++ when using templates, an exception can emanate from any operation on the template class. Be very careful!

```
template < class X >
X TemplateClass< X >::copy( ) {
  return X; // Might throw!! Invokes X's copy
  constructor!!
}
```

Return False

- An alternative to using exception handling is to have every method that might fail return a boolean. (This technique cannot be used with a constructor).

```
Vector< int > intVector;
boolean success = populateVector( intVector );
if( success ) { …; } // Use the now-filled intVector.
boolean populateVector( Vector< int >& intVector ) {
  try {
    intVector.add( 1 );
  }
  catch( … ) { return false; }
  return true;
}
```

A False Sense of Security

- Find the bug in the following Java code:

```
class Foo
{
  private int numFoos = 0;
  private int maxFoos = 10;
  private static FooList theFoos = new FooList( 10 );

  public void addFoo( Foo f ) throws FailedFooException
  {
    numFoos++;
    if( maxFoos < numFoos ) throw new FailedFooException( “Foo!” );
    theFoos.add( f );
  }
}
```

Null Pointers & Production Code

- Common programming error, even with experienced developers:

```
foo.bar();
```

- What if **`foo`** is **`null`**?
- In C++ the program will likely crash. In Java, it will throw a **`NullPointerException`**. Production code often looks more like this:

```
try {
  if( foo != null ) foo.bar();
}
catch( Exception ex ) { // Log and forget?
  Log.error( ”Unexpected Error Caught!", ex );
  return false;
}
return true;
```

Exception Handling Policy

- In Java, throw **`RuntimeExceptions`** to indicate programming errors.
- Throw “checked exceptions” when the caller might be able to recover.
- Don’t catch an exception if you cannot recover, unless you are at the highest level of the call stack, such as in main() or run(). In these cases, catch all exceptions to ensure they are logged, for debugging.
- If you do catch an exception, log it. Ensure that there is a process for automatically utilizing the logged information. Log file phishing to notice application defects is not acceptable for production systems.
- Exceptions should be logged exactly once, by design. Consider Log4J.
- Include as much information as you can, to aid debugging.
- Consider designing an application-specific subclass of **`RuntimeException`** for containing additional information about what caused the exception.
- A common example of a recoverable exception is in transactional database code, where the DBMS, upon detecting deadlock, will kill one of the two deadlocked processes at random. The failed transaction can be retried
- If using an application framework such as **`Spring`**, then study their E.H. policy in detail.

Design By Contract

An interface may be thought of as a *contract* that the implementing class is making with all of the interface's clients. "Design by Contract" is a theory that views an OO software system as collaborating components, whose interactions should strictly adhere to the terms of such contracts.

- Interfaces do not do a good job of defining *semantics*; and semantics should be well documented. Think like a lawyer and document as much as you can :^) Under what conditions might the software possibly fail?

Central to the theory of Design by Contract are pre-conditions & post-conditions for methods, and class invariants. It is easy to write code to check such conditions, and good *quality production code* is full of such checks.

- In C++, use **`assert`** statements liberally. **`assert( int expression )`** is a *macro* (that gets "compiled out" in production code if **`NDEBUG`** is defined), which will print an "nice" error and abort the program if the expression evaluates to 0 (logically also: null & false). Use this (or similar Java code) to check your code's assumptions. For example, **`assert( p );`** will fail if p is a null pointer.