

Object - Oriented Programming & Design

Part VI: Java Exception Handling

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Exception Handling

- Greatly simplify handling of exceptional, unexpected occurrences.
- Both C++ and Java support exceptions.
- Care must be taken (especially in C++) if you intend for the program to continue running.
- 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.
- A false sense of security? Not if designed carefully.

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Exception Handling (cont.)

- 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!" );
}
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!

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Exception Handling (cont.)

- 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.`

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Exception Handling (cont.)

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();
}
... // Elsewhere, myMethod() gets invoked ...
try {
    myMethod();
} catch( FooException fe ) { fe.printStackTrace(); }
```

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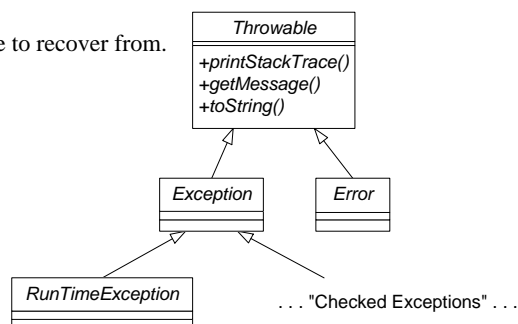
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Exception Handling (cont.)

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.



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Exception Handling (cont.)

```
Try
{
    throw new DatabaseException( "Deadlock detected!" );
}
catch( DatabaseException dbe )
{
    retryAfterDeadlock();
}
catch( Throwable t ) // Catch everything - Beware of Errors.
{
    log.Error( "Unexpected Problem! " + t ); // see: Log4j
}
```

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

```
catch( ... ) {}
```

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Exception Handling (cont.)

```
try {
    dbConnection.beginTransaction();
    boolean result = doDBTransaction( dbConnection, updateInfo );
    dbConnection.commitTransaction();
    return result;
}
catch( Throwable t ) { // Better: catch only expected exceptions
    dbConnection.rollbackTransaction();
    Log.getInstance().log( // Use Log4J
        "Transaction rolled back!", Severity.ERROR, t );
    return false;
}
finally { // This code gets executed no matter what.
    dbConnection.close(); // Frees system resources.
}
```

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Exception Handling (cont.)

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

- The goal is to ensure that every member function of an object 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 member 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 (variable) template class. Be very careful!

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

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Exception Handling (cont.)

- An alternative to using exception handling is to have every method that might fail simply 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;
}
```

- Note that `intVector` is *Passed by Reference* (note the `&`); otherwise the parameter would have *Copy Semantics* A.K.A. *Pass by Value*...

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Exception Handling (cont.)

- 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 );
    }
}
```

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Null Pointers

- 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();
    else return false;
}
catch( Exception ex ) { // Log and forget? Design something better.
    Log.error( "Unexpected Error Caught!", ex ); // See: Log4j
    return false;
}
return true;
```

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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.

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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.

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