Module 8

Exceptions and Assertions

Objectives

- Define exceptions
- Use `try`, `catch`, and `finally` statements
- Describe exception categories
- Identify common exceptions
- Develop programs to handle your own exceptions
- Use assertions
- Distinguish appropriate and inappropriate uses of assertions
- Enable assertions at runtime

Relevance

- In most programming languages, how do you resolve runtime errors?
- If you make assumptions about the way your code works, and those assumptions are wrong, what might happen?
- Is it always necessary or desirable to expend CPU power testing assertions in production programs?

Exceptions and Assertions

- Exceptions handle unexpected situations – Illegal argument, network failure, or file not found
- Assertions document and test programming assumptions – *This can never be negative here*
- Assertion tests can be removed entirely from code at runtime, so the code is not slowed down at all.

Exceptions

- Conditions that can readily occur in a correct program are *checked exceptions*.

  These are represented by the `Exception` class.

- Severe problems that normally are treated as fatal or situations that probably reflect program bugs are *unchecked exceptions*.

  Fatal situations are represented by the `Error` class.

  Probable bugs are represented by the `RuntimeException` class.

- The API documentation shows checked exceptions that can be thrown from a method.

Exception Example

```
1   public class AddArguments {
2     public static void main(String args[]) {
3       int sum = 0;
4       for ( String arg : args ) {
5         sum += Integer.parseInt(arg);
6       }
7       System.out.println("Sum = " + sum);
8     }
9   }
```

```
java AddArguments 1 2 3 4
Sum = 10
```

```
java AddArguments 1 two 3.0 4
Exception in thread "main" java.lang.NumberFormatException: For input string: "two"
    at java.lang.NumberFormatException.forInputString(NumberFormatException.java:48)
    at java.lang.Integer.parseInt(Integer.java:447)
    at java.lang.Integer.parseInt(Integer.java:497)
    at AddArguments.main(AddArguments.java:5)
```

The `try-catch` Statement

```java
public class AddArguments2 {
  public static void main(String args[]) {
    try {
      int sum = 0;
      for ( String arg : args ) {
        sum += Integer.parseInt(arg);
      }
      System.out.println("Sum = " + sum);
    } catch (NumberFormatException nfe) {
      System.err.println("One of the command-line "
                         + "arguments is not an integer.");
    }
  }
}
```

```
java AddArguments2 1 two 3.0 4
One of the command-line arguments is not an integer.
```

The `try-catch` Statement

```java
public class AddArguments3 {
  public static void main(String args[]) {
    int sum = 0;
    for ( String arg : args ) {
      try {
        sum += Integer.parseInt(arg);
      } catch (NumberFormatException nfe) {
        System.err.println("[" + arg + "] is not an integer"
                           + " and will not be included in the sum.");
      }
    }
    System.out.println("Sum = " + sum);
  }
}
```

```
java AddArguments3 1 two 3.0 4
[two] is not an integer and will not be included in the sum.
[3.0] is not an integer and will not be included in the sum.
Sum = 5
```

The `try-catch` Statement

A `try-catch` statement can use multiple catch clauses:

```
try {
  // code that might throw one or more exceptions

} catch (MyException e1) {
  // code to execute if a MyException exception is thrown

} catch (MyOtherException e2) {
  // code to execute if a MyOtherException exception is thrown

} catch (Exception e3) {
  // code to execute if any other exception is thrown
}
```

Call Stack Mechanism

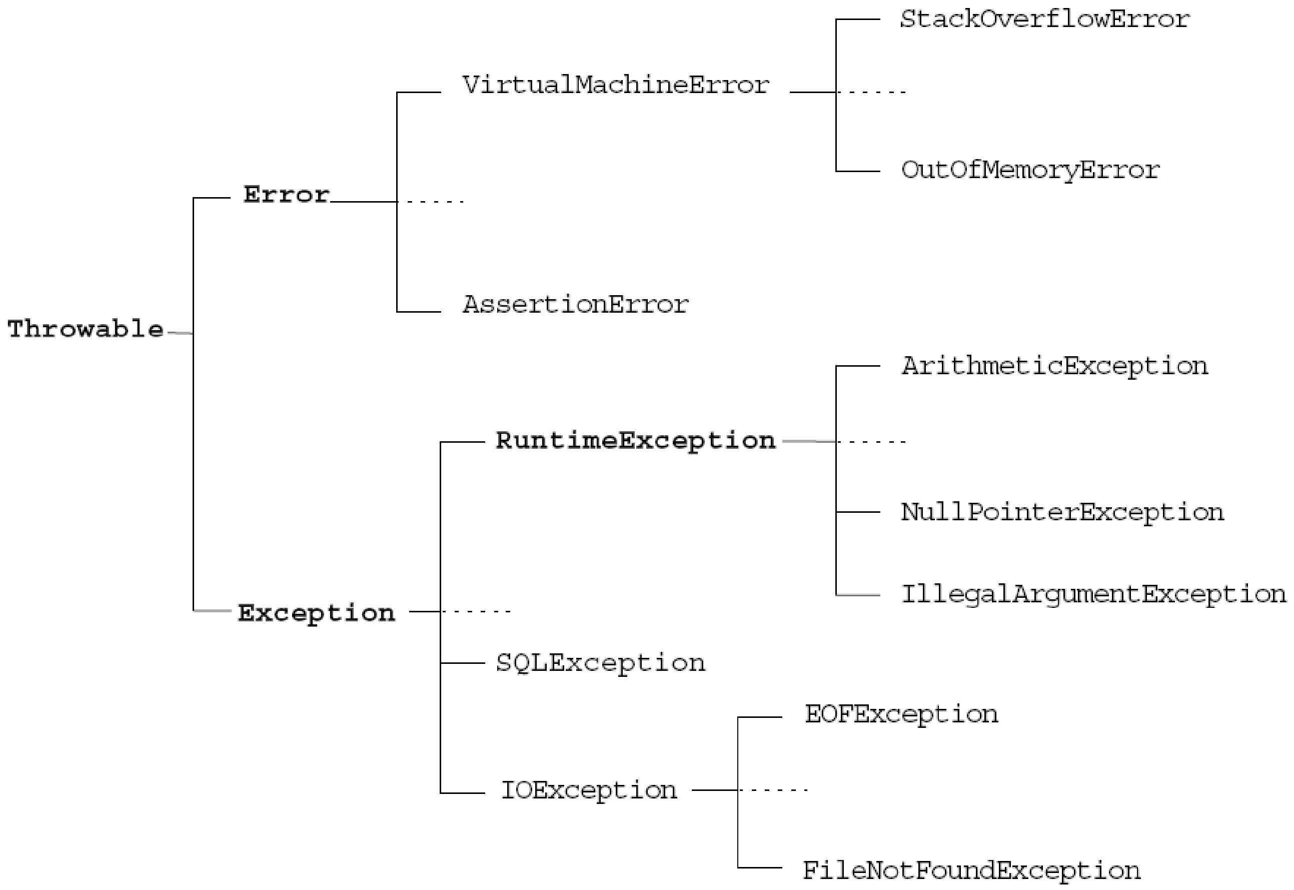
- If an exception is not handled in the current `try-catch` block, it is thrown to the caller of that method.
- If the exception gets back to the main method and is not handled there, the program is terminated abnormally.

The `finally` Clause

The `finally` clause defines a block of code that *always* executes.

```
try {
  startFaucet();
  waterLawn();
} catch (BrokenPipeException e) {
  logProblem(e);
} finally {
  stopFaucet();
}
```

Exception Categories



Common Exceptions

- `NullPointerException`
- `FileNotFoundException`
- `NumberFormatException`
- `ArithmeticException`
- `SecurityException`

The Handle or Declare Rule

Use the handle or declare rule as follows:

- Handle the exception by using the `try-catch-finally` block.
- Declare that the code causes an exception by using the `throws` clause.

```
void trouble() throws IOException { ... }
void trouble() throws IOException, MyException { ... }
```

Other Principles

- You do not need to declare runtime exceptions or errors.
- You can choose to handle runtime exceptions.

Method Overriding and Exceptions

The overriding method can throw:

- No exceptions
- One or more of the exceptions thrown by the overridden method
- One or more subclasses of the exceptions thrown by the overridden method

The overriding method cannot throw:

- Additional exceptions not thrown by the overridden method
- Superclasses of the exceptions thrown by the overridden method

Method Overriding and Exceptions

```java
public class TestA {
  public void methodA() throws IOException {
    // do some file manipulation
  }
}
```

```java
public class TestB1 extends TestA {
  public void methodA() throws EOFException {
    // do some file manipulation
  }
}
```

```java
public class TestB2 extends TestA {
  public void methodA() throws Exception { // WRONG
    // do some file manipulation
  }
}
```

Creating Your Own Exceptions

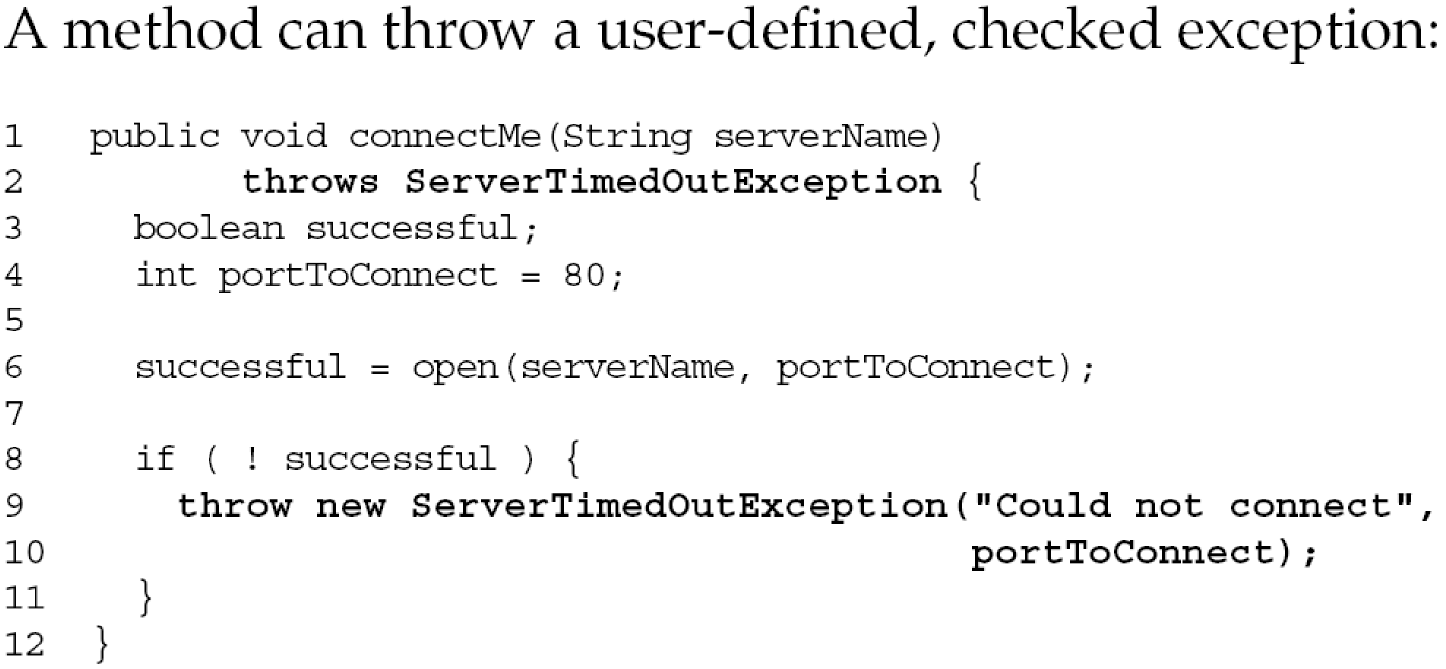
```
public class ServerTimedOutException extends Exception {
  private int port;

  public ServerTimedOutException(String message, int port) {
    super(message);
    this.port = port;
  }

  public int getPort() {
    return port;
  }
}
```

Use the `getMessage` method, inherited from the `Exception` class, to get the reason for which the exception was made.

Handling a User-Defined Exception



A method can throw a user-defined, checked exception:

```
public void connectMe(String serverName)
       throws ServerTimedOutException {
  boolean successful;
  int portToConnect = 80;

  successful = open(serverName, portToConnect);

  if ( ! successful ) {
    throw new ServerTimedOutException("Could not connect",
                                          portToConnect);
  }
}
```

Handling a User-Defined Exception

Another method can use a `try-catch` block to capture user-defined exceptions:

```
public void findServer() {
    try {
      connectMe(defaultServer);
    } catch (ServerTimedOutException e) {
      System.out.println("Server timed out, trying alternative");
      try {
        connectMe(alternativeServer);
      } catch (ServerTimedOutException e1) {
        System.out.println("Error: " + e1.getMessage() +
                           " connecting to port " + e1.getPort());
      }
    }
  }
```

Assertions

- Syntax of an assertion is:

```
assert <boolean_expression> ;
assert <boolean_expression> : <detail_expression> ;
```

- If `<boolean_expression>` evaluates `false`, then an `AssertionError` is thrown.
- The second argument is converted to a string and used as descriptive text in the `AssertionError` message.

Recommended Uses of Assertions

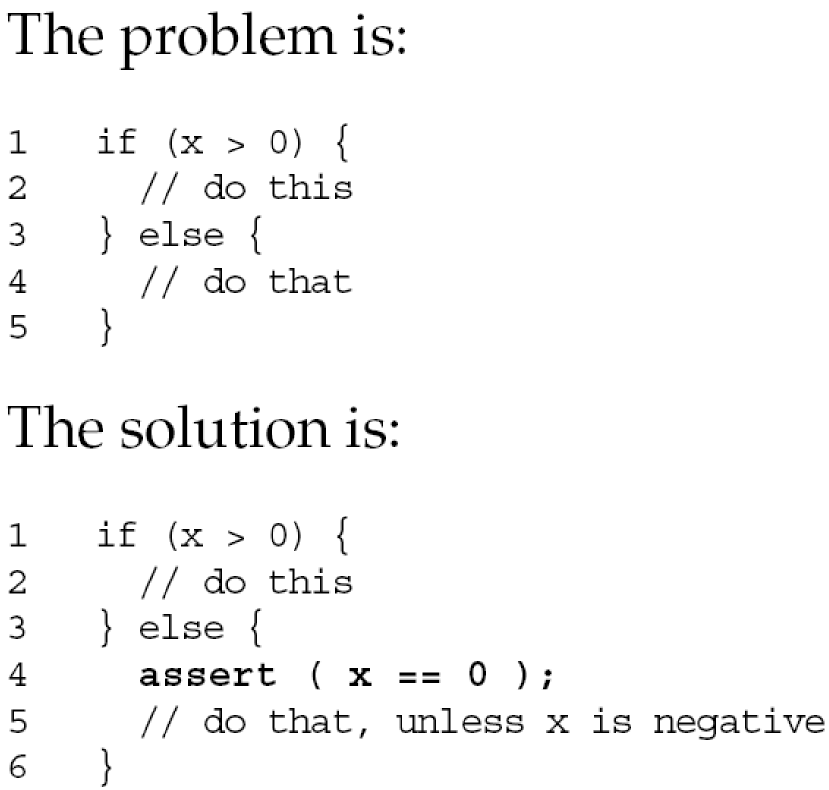
Use assertions to document and verify the assumptions and internal logic of a single method:

- Internal invariants
- Control flow invariants
- Postconditions and class invariants

Inappropriate Uses of Assertions

- Do not use assertions to check the parameters of a public method.
- Do not use methods in the assertion check that can cause side-effects.

Internal Invariants



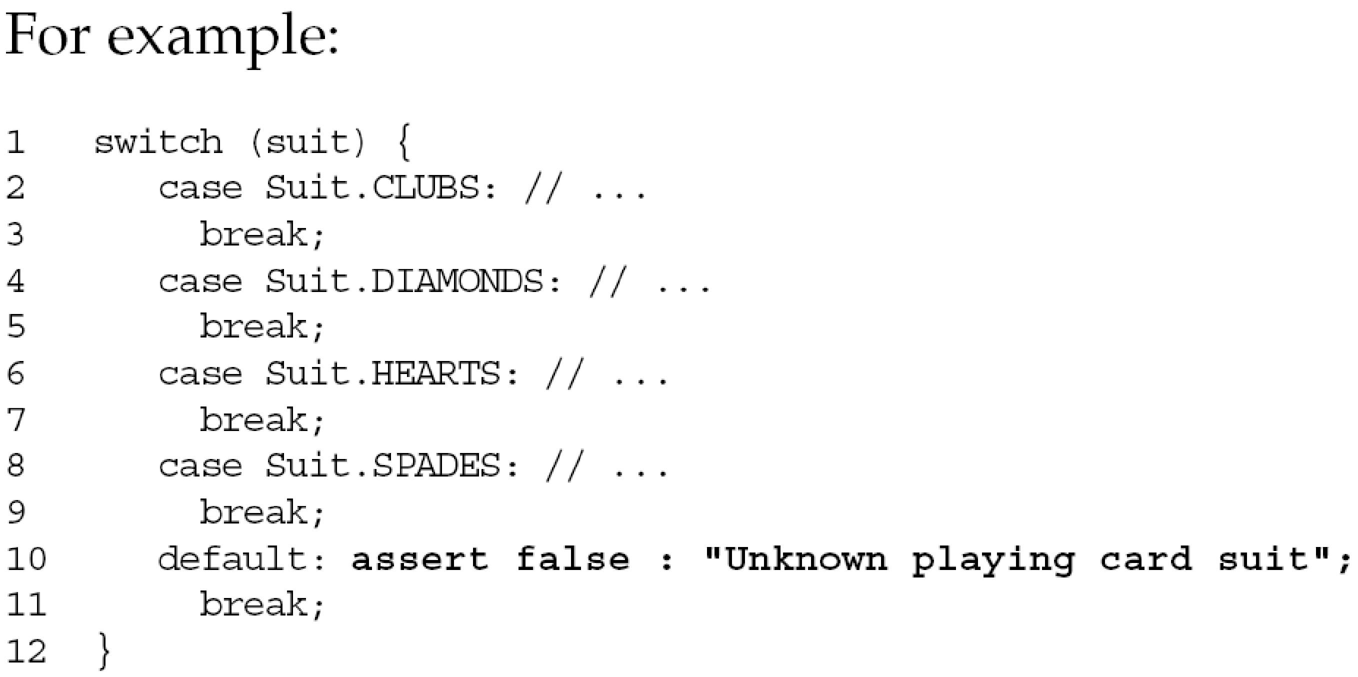
The problem is:

```
if (x > 0) {
  // do this
} else {
  // do that
}
```

The solution is:

```
if (x > 0) {
  // do this
} else {
  assert ( x == 0 );
  // do that, unless x is negative
}
```

Control Flow Invariants



For example:

```
switch (suit) {
   case Suit.CLUBS: // ...
     break;
   case Suit.DIAMONDS: // ...
     break;
   case Suit.HEARTS: // ...
     break;
   case Suit.SPADES: // ...
     break;
   default: assert false : "Unknown playing card suit";
     break;
}
```

Postconditions and Class Invariants

For example:

```
public Object pop() {
  int size = this.getElementCount();
  if (size == 0) {
    throw new RuntimeException("Attempt to pop from empty stack");
  }

  Object result = /* code to retrieve the popped element */ ;

  // test the postcondition
  assert (this.getElementCount() == size - 1);

  return result;
}
```

Controlling Runtime Evaluation of Assertions

- If assertion checking is disabled, the code runs as fast as if the check was never there.
- Assertion checks are disabled by default. Enable assertions with the following commands:

  ```
  java -enableassertions MyProgram
  ```

  or:

  ```
  java -ea MyProgram
  ```

- Assertion checking can be controlled on class, package, and package hierarchy bases, see:
  `docs/guide/language/assert.html`