Introduction to Exception Handling

Sometimes the best outcome can be when nothing unusual happens.

However, the case where exceptional things happen must also be prepared for.

- Java exception handling facilities are used when the invocation of a method may cause something exceptional to occur.
- Often the exception is some type of error condition.

try-throw-catch Mechanism

- The basic way of handling exceptions in Java consists of the *try-throw-catch* trio.
- The *try* block contains the code for the basic algorithm.
  - It tells what to do when everything goes smoothly.
- It is called a *try* block because it "tries" to execute the case where all goes as planned.
  - It can also contain code that throws an exception if something unusual happens.

```java
try {
    CodeThatMayThrowAnException
}
```
try-throw-catch Mechanism

throw new ExceptionClassName(PossiblySomeArguments);

• When an exception is thrown, the execution of the surrounding try block is stopped
  – Normally, the flow of control is transferred to another portion of code known as the catch block
• The value thrown is the argument to the throw operator, and is always an object of some exception class
  – The execution of a throw statement is called throwing an exception

try-throw-catch Mechanism

• When an exception is thrown, the catch block begins execution
  – The catch block has one parameter
  – The exception object thrown is plugged in for the catch block parameter
• The execution of the catch block is called catching the exception, or handling the exception
  – Whenever an exception is thrown, it should ultimately be handled (or caught) by some catch block

try-throw-catch Mechanism

A throw statement is similar to a method call:

throw new ExceptionClassName(SomeString);

– In the above example, the object of class ExceptionClassName is created using a string as its argument
– This object, which is an argument to the throw operator, is the exception object thrown
• Instead of calling a method, a throw statement calls a catch block

try-throw-catch Mechanism

catch(Exception e)
{
   ExceptionHandlingCode
}

• A catch block looks like a method definition that has a parameter of type Exception class
  – It is not really a method definition, however
• A catch block is a separate piece of code that is executed when a program encounters and executes a throw statement in the preceding try block
  – A catch block is often referred to as an exception handler
  – It can have at most one parameter
try-throw-catch Mechanism

```java
catch(Exception e) {
    // code
}
```

- The identifier `e` in the above `catch` block heading is called the `catch` block parameter.
- The `catch` block parameter does two things:
  1. It specifies the type of thrown exception object that the `catch` block can catch (e.g., an `Exception` class object above).
  2. It provides a name (for the thrown object that is caught) on which it can operate in the `catch` block.
     - Note: The identifier `e` is often used by convention, but any non-keyword identifier can be used.

When a `try` block is executed, two things can happen:

1. No exception is thrown in the `try` block
   - The code in the `try` block is executed to the end of the block.
   - The `catch` block is skipped.
   - The execution continues with the code placed after the `catch` block.

2. An exception is thrown in the `try` block and caught in the `catch` block.
   - The rest of the code in the `try` block is skipped.
   - Control is transferred to a following `catch` block (in simple cases).
   - The thrown object is plugged in for the `catch` block parameter.
   - The code in the `catch` block is executed.
   - The code that follows that `catch` block is executed (if any).

Exception Example

- In many cases your own code doesn’t throw the exception, but instead it is thrown by an existing Java library.
- Example: Input an integer using `nextInt()`
  - What if the user doesn’t enter an integer?
    - The `nextInt` method throws an `InputMismatchException`.

Exception Handling with the **Scanner** Class

- If a user enters something other than a well-formed `int` value, an **InputMismatchException** will be thrown
  - Unless this exception is caught, the program will end with an error message
  - If the exception is caught, the **catch** block can give code for some alternative action, such as asking the user to reenter the input

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**The InputMismatchException**

- The **InputMismatchException** is in the standard Java package `java.util`
  - A program that refers to it must use an `import` statement, such as the following:
    ```java
    import java.util.InputMismatchException;
    ```
- It is a descendent class of **RuntimeException**
  - Therefore, it is an unchecked exception and does not have to be caught in a **catch** block or declared in a **throws** clause
  - However, catching it in a **catch** block is allowed, and can sometimes be useful

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**Tip: Exception Controlled Loops**

- Sometimes it is better to simply loop through an action again when an exception is thrown, as follows:
  ```java
  boolean done = false;
  while (! done)
  {
    try
    {
      CodeThatMayThrowAnException
      done = true;
    }
    catch (SomeExceptionClass e)
    {
      SomeMoreCode
    }
  }
  ```

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**Exception Controlled Loop**

```java
Display 9.1 An Exception Controlled Loop
1. import java.util.Scanner;
2. import java.util.InputMismatchException;
3. public class InputMismatchExceptionDemo
4. {
5.   public static void main(String[] args)
6.   {
7.     while (true) // Do not use false in catch block
8.     {
9.       System.out.println("Enter a number: ");
10.      Number = keyboard.nextInt();
11.      done = true;
12.      } // End while
13.      break;
14.     }
15.   }
16.   input.nextLine();
17.   System.out.println("Not a correctly written number.");
18.   System.out.println("Try again.");
19.   Number = keyboard.nextInt();
20.   done = true;
21. } // End catch
22. System.out.println("Enter a number: ");
23. Number = keyboard.nextInt();
24. done = true;
25. System.out.println("You entered "+ Number);
26. System.out.println("You entered ");
```
Exception Classes

- There are more exception classes than just the single class `Exception`
  - There are more exception classes in the standard Java libraries
  - New exception classes can be defined like any other class
- All predefined exception classes have the following properties:
  - There is a constructor that takes a single argument of type `String`
  - The class has an accessor method `getMessage` that can recover the string given as an argument to the constructor when the exception object was created
- All programmer-defined classes should have the same properties

Exception Classes from Standard Packages

- Numerous predefined exception classes are included in the standard Java packages that come with Java
  - For example:
    ```java
    IOException
    NoSuchMethodException
    FileNotFoundException
    ```
  - Many exception classes must be imported in order to use them
    ```java
    import java.io.IOException;
    ```

Using the `getMessage` Method

- The predefined exception class `Exception` is the root class for all exceptions
  - Every exception class is a descendant of the class `Exception`
  - Although the `Exception` class can be used directly in a class or program, it is most often used to define a derived class
  - The class `Exception` is in the `java.lang` package, and so requires no `import` statement

```java
// method code
try {
    ...
    throw new Exception(StringArgument);
    ...
} catch(Exception e) {
    String message = e.getMessage();
    System.out.println(message);
    System.exit(0);
}  ...
```
Using the `getMessage` Method

- Every exception has a `String` instance variable that contains some message
  - This string typically identifies the reason for the exception
- In the previous example, `StringArgument` is an argument to the `Exception` constructor
- This is the string used for the value of the `String` instance variable of exception `e`
  - Therefore, the method call `e.getMessage()` returns this string

Defining Exception Classes

- A `throw` statement can throw an exception object of any exception class
- Instead of using a predefined class, exception classes can be programmer-defined
  - These can be tailored to carry the precise kinds of information needed in the `catch` block
  - A different type of exception can be defined to identify each different exceptional situation

Defining Exception Classes

- Every exception class to be defined must be a derived class of some already defined exception class
  - It can be a derived class of any exception class in the standard Java libraries, or of any programmer defined exception class
- Constructors are the most important members to define in an exception class
  - They must behave appropriately with respect to the variables and methods inherited from the base class
  - Often, there are no other members, except those inherited from the base class
- The following exception class performs these basic tasks only

A Programmer-Defined Exception Class

```
public class DivisionByZeroException extends Exception
{
    public DivisionByZeroException()
    {
        super("Division by Zero!");
    }

    public DivisionByZeroException(String message)
    {
        super(message);
    }
}
```
Using our own Exception Class (1 of 3)

```java
import java.util.Scanner;

public class DivisionDemoFirstVersion {

    public static void main(String[] args) {
        Scanner keyboard = new Scanner(System.in);

        System.out.println("Enter numerator:");
        int numerator = keyboard.nextInt();

        System.out.println("Enter denominator:");
        int denominator = keyboard.nextInt();
    }
}
```

Using our own Exception Class (2 of 3)

```java
if (denominator == 0)
    throw new DivisionByZeroException();

double quotient = numerator/(double)denominator;
System.out.println("Numerator "+ numerator + "/
    + denominator + "+ quotient);
    
    try {
    
    
    
    
    catch (DivisionByZeroException e) {
        System.out.println(e.getMessage());
        secondChance();
    }

    System.out.println("End of program.");
}
```

Using our own Exception Class (3 of 3)

```java
public static void secondChance() {
    Scanner keyboard = new Scanner(System.in);

    System.out.println("Enter numerator:");
    int numerator = keyboard.nextInt();

    System.out.println("Enter denominator:");
    int denominator = keyboard.nextInt();

    if (denominator == 0) {
        System.out.println("I cannot do division by zero.");
        System.out.println("Aborting program.");
        System.exit(9);
    }

    double quotient = (double)numerator/denominator;
    System.out.println(" = " + quotient);
```

Tip: An Exception Class Can Carry a Message of Any Type: int Message

- An exception class constructor can be defined that takes an argument of another type
  - It would store its value in an instance variable
  - It would need to define accessor methods for this instance variable
An Exception Class with an \textit{int} Message

```java
public class BadNumberException extends Exception {
    private int badNumber;

    public BadNumberException(int number) {
        super("BadNumberException");
        badNumber = number;
    }

    public BadNumberException() {
        super("BadNumberException");
    }

    public BadNumberException(String message) {
        super(message);
    }

    public int getBadNumber() {
        return badNumber;
    }
}
```

Exception Object Characteristics

- The two most important things about an exception object are its type (i.e., exception class) and the message it carries
  - The message is sent along with the exception object as an instance variable
  - This message can be recovered with the accessor method \texttt{getMessage}, so that the catch block can use the message

Programmer-Defined Exception Class Guidelines

- Exception classes may be programmer-defined, but every such class must be a derived class of an already existing exception class
- The class \texttt{Exception} can be used as the base class, unless another exception class would be more suitable
- At least two constructors should be defined, sometimes more
- The exception class should allow for the fact that the method \texttt{getMessage} is inherited

Preserve \texttt{getMessage}

- For all predefined exception classes, \texttt{getMessage} returns the string that is passed to its constructor as an argument
  - Or it will return a default string if no argument is used with the constructor
- This behavior must be preserved in all programmer-defined exception class
  - A constructor must be included having a string parameter whose body begins with a call to \texttt{super}
  - The call to \texttt{super} must use the parameter as its argument
  - A no-argument constructor must also be included whose body begins with a call to \texttt{super}
  - This call to \texttt{super} must use a default string as its argument
Multiple catch Blocks

- A try block can potentially throw any number of exception values, and they can be of differing types
  - In any one execution of a try block, at most one exception can be thrown (since a throw statement ends the execution of the try block)
  - However, different types of exception values can be thrown on different executions of the try block

Each catch block can only catch values of the exception class type given in the catch block heading

- Different types of exceptions can be caught by placing more than one catch block after a try block
  - Any number of catch blocks can be included, but they must be placed in the correct order

Pitfall: Catch the More Specific Exception First

- When catching multiple exceptions, the order of the catch blocks is important
  - When an exception is thrown in a try block, the catch blocks are examined in order
  - The first one that matches the type of the exception thrown is the one that is executed

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

- Because a NegativeNumberException is a type of Exception, all NegativeNumberExceptions will be caught by the first catch block before ever reaching the second block
  - The catch block for NegativeNumberException will never be used!
- For the correct ordering, simply reverse the two blocks
Declaring Exceptions in a `throws` Clause

- If a method can throw more than one type of exception, then separate the exception types by commas
  ```java
  public void aMethod() throws AnException, AnotherException
  ```
- If a method throws a warning that it can throw an exception and does not catch it, it must provide a warning
  - This warning is called a `throws clause`
  - The process of including an exception class in a throws clause is called declaring the exception
    ```java
    throws AnException // throws clause
    ```
  - The following states that an invocation of `aMethod` could throw `AnException`
    ```java
    public void aMethod() throws AnException
    ```

The Catch or Declare Rule

- Most ordinary exceptions that might be thrown within a method must be accounted for in one of two ways:
  1. The code that can throw an exception is placed within a `try` block, and the possible exception is caught in a `catch` block within the same method
  2. The possible exception can be declared at the start of the method definition by placing the exception class name in a `throws` clause
The Catch or Declare Rule

- The first technique handles an exception in a `catch` block
- The second technique is a way to shift the exception handling responsibility to the method that invoked the exception throwing method
- The invoking method must handle the exception, unless it too uses the same technique to "pass the buck"
- Ultimately, every exception that is thrown should eventually be caught by a `catch` block in some method that does not just declare the exception class in a `throws` clause

Checked and Unchecked Exceptions

- Exceptions that are subject to the catch or declare rule are called `checked` exceptions
  - The compiler checks to see if they are accounted for with either a catch block or a throws clause
  - The classes `Throwable`, `Exception`, and all descendants of the class `Exception` are checked exceptions
- All other exceptions are `unchecked` exceptions
- The class `Error` and all its descendant classes are called `error classes`
  - Error classes are not subject to the Catch or Declare Rule

The Catch or Declare Rule

- In any one method, both techniques can be mixed
  - Some exceptions may be caught, and others may be declared in a `throws` clause
- However, these techniques must be used consistently with a given exception
  - If an exception is not declared, then it must be handled within the method
  - If an exception is declared, then the responsibility for handling it is shifted to some other calling method
  - Note that if a method definition encloses an invocation of a second method, and the second method can throw an exception and does not catch it, then the first method must catch or declare it

Exceptions to the Catch or Declare Rule

- Checked exceptions must follow the Catch or Declare Rule
  - Programs in which these exceptions can be thrown will not compile until they are handled properly
- Unchecked exceptions are exempt from the Catch or Declare Rule
  - Programs in which these exceptions are thrown simply need to be corrected, as they result from some sort of error
The throws Clause in Derived Classes

- When a method in a derived class is overridden, it should have the same exception classes listed in its `throws` clause that it had in the base class
  - Or it should have a subset of them
- A derived class may not add any exceptions to the `throws` clause
  - But it can delete some

What Happens If an Exception is Never Caught?

- If every method up to and including the main method simply includes a `throws` clause for an exception, that exception may be thrown but never caught
  - In a GUI program (i.e., a program with a windowing interface), nothing happens - but the user may be left in an unexplained situation, and the program may be no longer be reliable
  - In non-GUI programs, this causes the program to terminate with an error message giving the name of the exception class
- Every well-written program should eventually catch every exception by a `catch` block in some method

When to Use Exceptions

- Exceptions should be reserved for situations where a method encounters an unusual or unexpected case that cannot be handled easily in some other way
- When exception handling must be used, here are some basic guidelines:
  - Include `throw` statements and list the exception classes in a `throws` clause within a method definition
  - Place the `try` and `catch` blocks in a different method
When to Use Exceptions

• Here is an example of a method from which the exception originates:

```java
public void someMethod()
    throws SomeException
{
    // ...
    throw new
    SomeException(SomeArgument);
    // ...
}
```

When to Use Exceptions

• When `someMethod` is used by an `otherMethod`, the `otherMethod` must then deal with the exception:

```java
public void otherMethod()
{
    try
    {
        someMethod();
        // ...
    }
    catch (SomeException e)
    {
        CodeToHandleException
        // ...
    }
}
```

Event Driven Programming

• Exception handling is an example of a programming methodology known as *event-driven programming*

• When using event-driven programming, objects are defined so that they send events to other objects that handle the events
  – An event is an object also
  – Sending an event is called *firing an event*

Event Driven Programming

• In exception handling, the event objects are the exception objects
  – They are fired (thrown) by an object when the object invokes a method that throws the exception
  – An exception event is sent to a `catch` block, where it is handled
Pitfall: Nested try-catch Blocks

- It is possible to place a try block and its following catch blocks inside a larger try block, or inside a larger catch block
  - If a set of try-catch blocks are placed inside a larger catch block, different names must be used for the catch block parameters in the inner and outer blocks, just like any other set of nested blocks.
  - If a set of try-catch blocks are placed inside a larger try block, and an exception is thrown in the inner try block that is not caught, then the exception is thrown to the outer try block for processing, and may be caught in one of its catch blocks.

The finally Block

- The finally block contains code to be executed whether or not an exception is thrown in a try block
  - If it is used, a finally block is placed after a try block and its following catch blocks
    ```java
    try
    { . . . }
    catch (ExceptionClass1 e)
    { . . . }
    . . .
    catch (ExceptionClassN e)
    { . . . }
    finally
    {
        CodeToBeExecutedInAllCases
    }
    ```

Rethrowing an Exception

- A catch block can contain code that throws an exception
  - Sometimes it is useful to catch an exception and then, depending on the string produced by `getMessage` (or perhaps something else), throw the same or a different exception for handling further up the chain of exception handling blocks.
The **AssertionError** Class

- When a program contains an assertion check, and the assertion check fails, an object of the class **AssertionError** is thrown
  - This causes the program to end with an error message
- The class **AssertionError** is derived from the class **Error**, and therefore is an unchecked exception
  - In order to prevent the program from ending, it could be handled, but this is not required

**ArrayIndexOutOfBoundsException**

- An **ArrayIndexOutOfBoundsException** is thrown whenever a program attempts to use an array index that is out of bounds
  - This normally causes the program to end
- Like all other descendents of the class **RuntimeException**, it is an unchecked exception
  - There is no requirement to handle it
- When this exception is thrown, it is an indication that the program contains an error
  - Instead of attempting to handle the exception, the program should simply be fixed