Module 13 - Handling Exceptions

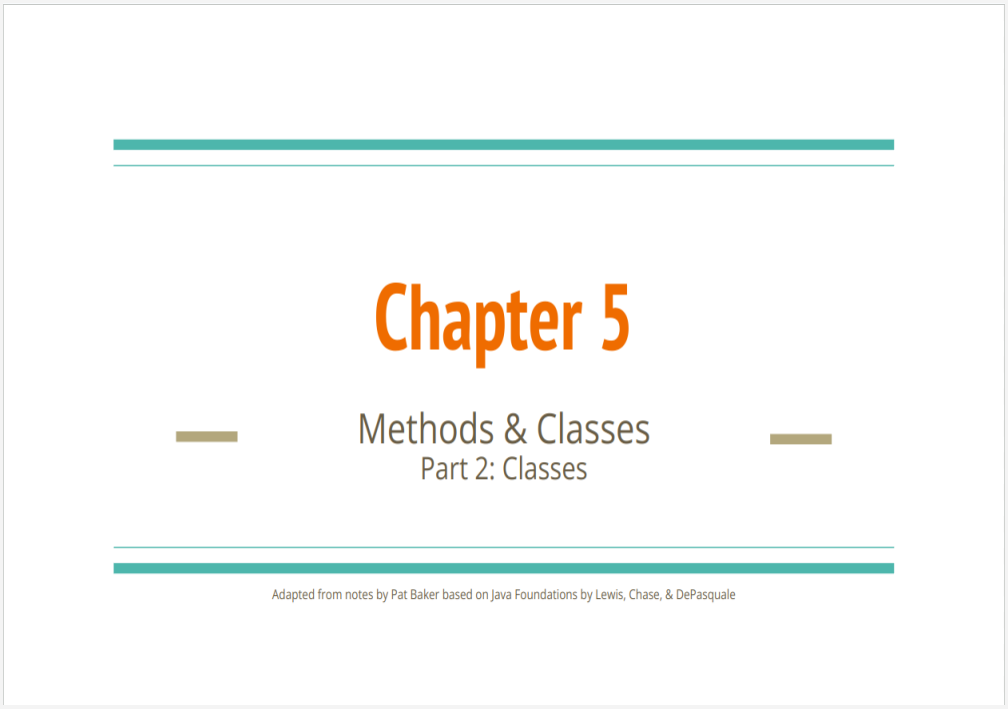
General Notes

Module Content

Notes

Google Slides:

Link



Instructor Notes:

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Java Foundations Notes
Chapter 5 (part 2) - Classes

CSC110

Object-Oriented Programming

Java is an **Object-Oriented Programming** language. (OK, that isn't 100% true, but it is close enough for our purposes.) The fundamental entity is the "**object**" An object has some information (**state**) & some operations (**behaviors**) and usually represents some real-world entity such as:

- A particular student in a class
- A window in a GUI
- A character in a game

Objects should handle their own processing and data management.

Object-Oriented languages vary widely, but typically the contain the following features, often called "The Four Pillars of Object-Oriented Programming":

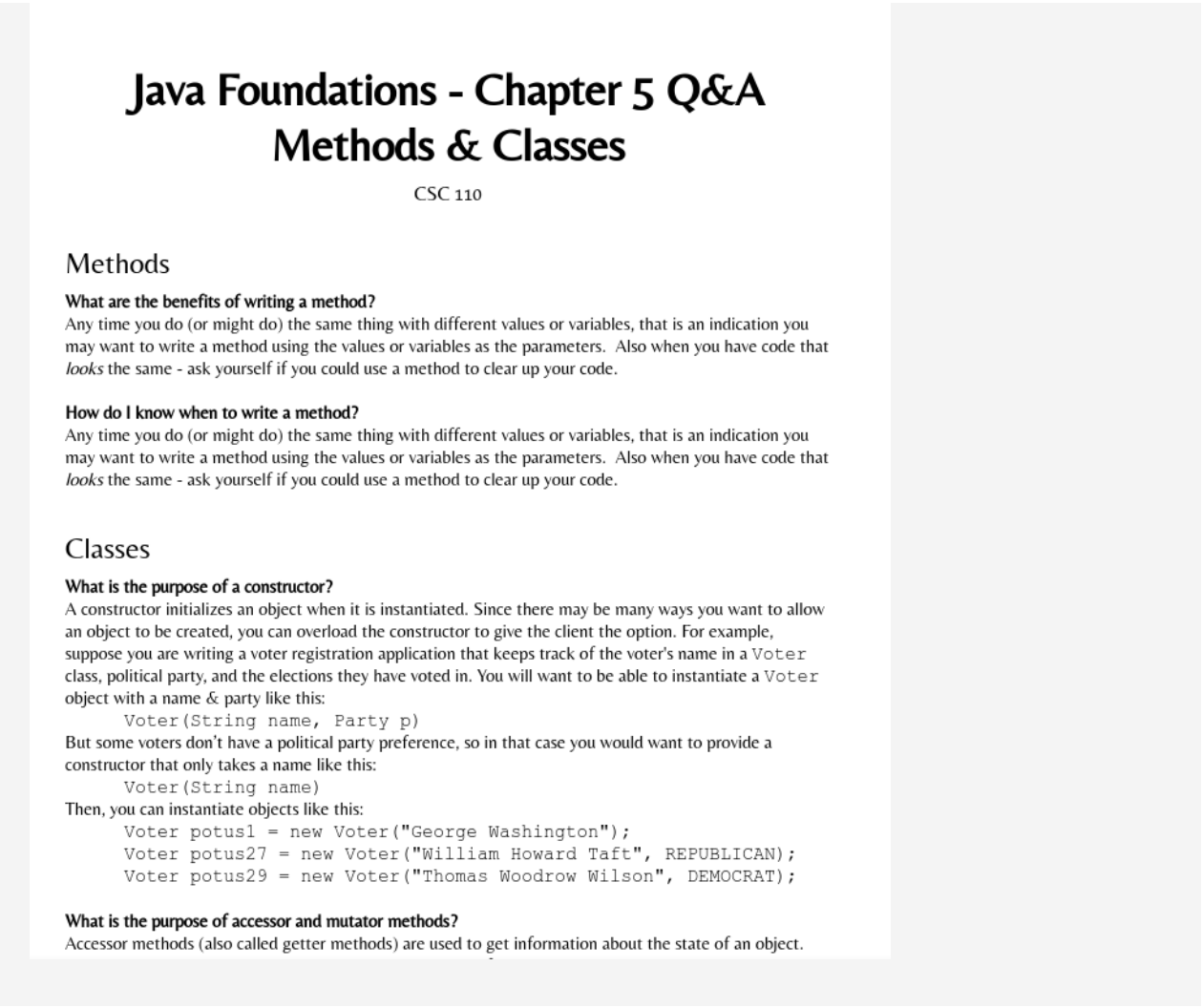
- **Abstraction** - shifting the focus on what an object does instead of the details of its implementation
- **Encapsulation** - separating the interface from the implementation
- **Inheritance** - subclasses can include attributes & methods from a superclass
- **Polymorphism** - methods get called based on the type of the object no matter what the type of the reference is (late-binding)

The explanations above are by necessity fairly hand-wavy for now. We will discuss each of these in more detail later.

In Object-Oriented Programming there are usually multiple ways to represent a problem and there is often no "one right answer". In fact, in many cases OOP itself is not always the answer (though for purposes of this class it will nearly always be). In practice, there are usually multiple ways to solve a problem, with a few of them being good choices. There are also lots of ways to poorly solve a problem, which is why experience is your best friend when it comes to programming. The more you practice the better you will get.

Instructor Q&A:

Link



Java Foundations - Chapter 5 Q&A
Methods & Classes

CSC 110

Methods

What are the benefits of writing a method?
Any time you do (or might do) the same thing with different values or variables, that is an indication you may want to write a method using the values or variables as the parameters. Also when you have code that *looks* the same - ask yourself if you could use a method to clear up your code.

How do I know when to write a method?
Any time you do (or might do) the same thing with different values or variables, that is an indication you may want to write a method using the values or variables as the parameters. Also when you have code that *looks* the same - ask yourself if you could use a method to clear up your code.

Classes

What is the purpose of a constructor?
A constructor initializes an object when it is instantiated. Since there may be many ways you want to allow an object to be created, you can overload the constructor to give the client the option. For example, suppose you are writing a voter registration application that keeps track of the voter's name in a `Voter` class, political party, and the elections they have voted in. You will want to be able to instantiate a `Voter` object with a name & party like this:

```
Voter(String name, Party p)
```

But some voters don't have a political party preference, so in that case you would want to provide a constructor that only takes a name like this:

```
Voter(String name)
```

Then, you can instantiate objects like this:

```
Voter potus1 = new Voter("George Washington");
Voter potus27 = new Voter("William Howard Taft", REPUBLICAN);
Voter potus29 = new Voter("Thomas Woodrow Wilson", DEMOCRAT);
```

What is the purpose of accessor and mutator methods?
Accessor methods (also called getter methods) are used to get information about the state of an object.

Additional Resources

- **Book:**
  Think Java: How to Think Like a Computer Scientist
  by *Allen B. Downey and Chris Mayfield*
- **Video:**
  Overview of writing your own Classes and Creating Objects
- **Video:**
  an Account class and tester class. Similar to BankAccount
- **Video:**
  ArrayList Basics (Ch 10)
- **Video:**
  ArrayLists (Ch 10) - A dynamic Data structure
- **Video:**
  ArrayList: Array vs. ArrayList

ZyBooks

Handling Exceptions in Java

Unhandled exceptions

- An **exception** is an unexpected incident that stops the normal execution of a program.
  - *Example:* Dividing by zero or getting invalid input results in an exception.
- A program that does not handle an exception ends execution.

Catching exceptions

To avoid having a program end when an exception occurs, a program can use **try ** and **catch** blocks to handle the exception during program execution.

- A **try block** surrounds normal code, which is exited immediately if a statement within the try block throws an exception.
- A **catch block** catches an exception thrown in a preceding try block. If the thrown exception's type matches the catch block's parameter type, the code within the catch block executes.
  - A catch block is called an **exception handler**.

Handling Exceptions

- A program may be able to resolve some exceptions.
- Instead of just printing the caught exception, a program can discard the current input line and get the distance from the user again.

Example: `LightTravelTime` Program

```
import java.util.Scanner;
import java.util.InputMismatchException;

public class LightTravelTime {
   public static void main(String[] args) {
      Scanner scnr = new Scanner(System.in);
      double distMiles = 0.0;
      double lightTravelTime = 0.0;
      boolean needInput = true;

      while (needInput) {
         System.out.print("Enter a distance in miles: ");

         try {
            distMiles = scnr.nextDouble();
            lightTravelTime = distMiles / 186282.0;
            needInput = false;
         }
         catch (InputMismatchException e) {
            scnr.nextLine(); // Throw away incorrect input
         }
      }

      System.out.println("Light travels " + distMiles +
                         " miles in " + lightTravelTime +
                         " seconds");
   }
}
```

- The program repeatedly prompts the user for input until a valid distance value is entered.
- The `try` block tries to get the distance from the user, and if an exception occurs, the `catch` block discards the current input line and prompts the user again.
- If no exception is thrown, the program exits the `while` loop and prints the result.

Common exception types

Type	Reason exception is thrown
EOFException	End of file or end of stream has been reached unexpectedly during input
InputMismatchException	Received input does not match expected type or the input is out of range for the expected type (thrown by Scanner)
ArrayIndexOutOfBoundsException	An array has been accessed with an illegal index (negative or greater than array size)
FileNotFoundException	Attempt to open a file denoted by a filename failed
ArithmeticException	Arithmetic condition failed (Ex: Divide by zero error)

- *Source: Java™ Platform API Specification*

Conclusion

- Exceptions are unexpected incidents that stop the normal execution of a program.
- Programs can use try and catch blocks to handle exceptions during program execution.
- Some exceptions can be resolved by discarding the current input line and prompting the user again.
- Different types of exceptions exist in Java, including EOFException, InputMismatchException, ArrayIndexOutOfBoundsException, FileNotFoundException, and ArithmeticException.

Throwing Exceptions

Using throw statements

- A **throw** statement throws a throwable object, like an exception, during program execution.
- A program can throw user-defined exceptions using a throw statement.

- *Ex:* `throw new Exception("Invalid date.");` creates and throws an exception with the message "Invalid date".

Using exceptions to separate error checking from normal code

- A programmer can detect errors and throw exceptions to keep error-checking code separate from normal code and to reduce redundant error checks.
- The program computes the density of an object by taking the ratio of mass and volume inputs.
- If either input is negative, the program throws an exception to handle the error.

```
import java.util.Scanner;

public class DensityCalculator {
   public static void main(String[] args) {
      Scanner scnr = new Scanner(System.in);
      double massVal = 0;   // Object mass (kg)
      double volumeVal = 0; // Object volume (m^3)
      double densityCalc;   // Resulting density

      try {
         massVal = scnr.nextDouble();

         // Error checking, non-negative mass
         if (massVal < 0.0) {
            throw new Exception("Invalid mass");
         }

         volumeVal = scnr.nextDouble();

         // Error checking, non-negative volume
         if (volumeVal < 0.0) {
            throw new Exception("Invalid volume");
         }

         densityCalc = massVal / volumeVal;

         System.out.print("Density: " + densityCalc);
      }
      catch (Exception excpt) {
         // Prints the error message passed by the throw statement.
         System.out.print(excpt.getMessage());
      }
   }
}
```

- The `getMessage()` method returns the `Exception` object's message.

Example outputs:

```
3.0 2.0
Density: 1.5
...
-1.0 2.0
Invalid mass
...
3.0 -1.0
Invalid volume
```

Multiple exception handlers

- Code within a try block may throw different types of exceptions.
- The program below computes a person's BMI from weight and height inputs.
- If any input is negative, the program throws an exception of type Exception.
- If any input is not an integer, Scanner's nextInt() method throws an exception of type InputMismatchException.

Example: BMI calculator with multiple exception handlers

```
import java.util.Scanner;
import java.util.InputMismatchException;

public class BMICalculator {
   public static void main(String[] args) {
      Scanner scnr = new Scanner(System.in);
      int weightVal = 0;    // User defined weight (lbs)
      int heightVal = 0;    // User defined height (in)
      double bmiCalc;        // Resulting BMI

      try {
         System.out.print("Enter weight (in pounds): ");
         weightVal = scnr.nextInt();

         // Error checking, non-negative weight
         if (weightVal < 0) {
            throw new Exception("Invalid weight.");
         }

         System.out.print("Enter height (in inches): ");
         heightVal = scnr.nextInt();

         // Error checking, non-negative height
         if (heightVal < 0) {
            throw new Exception("Invalid height.");
         }

         bmiCalc = ((double) weightVal /
                    (double) (heightVal * heightVal)) * 703.0f;

         System.out.println("BMI: " + bmiCalc);
      }
      catch (InputMismatchException excpt) {
         System.out.println("Expected a number as input.");
         System.out.println("Cannot compute BMI.");
      }
      catch (Exception excpt) {
         // Prints the error message passed by the throw statement.
         System.out.println(excpt.getMessage());
         System.out.println("Cannot compute BMI.");
      }
```

```
    }
}
```

Example outputs:

````
```java
Enter weight (in pounds): 150
Enter height (in inches): 66
BMI: 24.207988980716255
...
Enter weight (in pounds): -1
Invalid weight.
Cannot compute BMI.
...
Enter weight (in pounds): 150
Enter height (in inches): sixty
Expected a number as input.
Cannot compute BMI.
```
````

Conclusion

- `throw` statements are used to throw exceptions in a program and can be used to handle errors and separate error-checking code from normal code.
- Multiple exception handlers can be used to catch different types of exceptions and provide custom messages for each case.

Exceptions with Methods

Specifying Exceptions Thrown by a Method

- A program may handle an exception outside of the method that throws the exception.
- The `throws` clause specifies the types of exceptions that a method may throw and callers of the method should handle.
- A `throws` clause is specified after a method's parameters list and before the opening brace.
- A `throws` clause may specify multiple exception types, separated by commas.

Checked vs Unchecked Exceptions

Java has two types of exceptions:

- **Checked**
  - A Checked exception is an exception that a programmer should be able to anticipate and handle.
    - *Ex:* A program that opens files should anticipate and handle a FileNotFoundException.
- **Unchecked**
  - An Unchecked exception is an exception caused by hardware or logic errors that
    a programmer usually cannot anticipate and handle.
    - *Ex:* A program should try to eliminate code that uses null references instead of catching and handling NullPointerException.

Java's **catch or specify requirement** requires methods to either catch a checked
exception using a `catch` block or specify that the method throws the checked exception using a `throws` clause.

- Code that does not obey the catch or specify requirement does not compile.

Unchecked exception	Notes
NullPointerException	Indicates a null reference.
IndexOutOfBoundsException	Indicates that an index (e.g., an index for an array) is outside the appropriate range.
ArithmeticException	Indicates the occurrence of an exceptional arithmetic condition (e.g., integer division by zero).
IOError	Indicates the failure of an I/O operation.
ClassCastException	Indicates an invalid attempt to cast an object to type of which the object is not an instance (e.g., casting a Double to a String).
IllegalArgumentException	Indicates an illegal or inappropriate method argument.

Throwing Exceptions in Methods Calling Other Methods

- A method may call another method with a `throws` clause.
- If the calling method does not handle the exception types thrown by the called method, the calling method's `throws` clause must specify all exception types thrown by the called method.

Hierarchical Methods Example: DataTimeSpeedup

- The program uses hierarchical method calls to print the speedup of the average time values in two files.
- The `calcAvgInputVal()` method may throw an exception of type `Exception` while reading from a Scanner.
- `calcAvgSpeedup()` calls `calcAvgInputVal()` and does not catch the `Exception` type.
- The `throws` clause for `calcAvgSpeedup()` must specify the type `Exception`.

```
import java.util.Scanner;
import java.io.FileInputStream;
import java.io.FileNotFoundException;

public class DataTimeSpeedup {
   public static double calcAvgInputVal(Scanner scnr) throws Exception {
      double sumVal = 0;
      int numValues = scnr.nextInt();

      if (numValues < 0) {
         throw new Exception("Negative number of values");
      }

      for (int i = 0; i < numValues; ++i) {
         sumVal += scnr.nextDouble();
      }

      return sumVal / (double) numValues;
   }

   public static double calcAvgSpeedup(String file1, String file2) throws
FileNotFoundException, Exception {
      FileInputStream inStream1 = new FileInputStream(file1);
      FileInputStream inStream2 = new FileInputStream(file2);
      Scanner fileScnr1 = new Scanner(inStream1);
      Scanner fileScnr2 = new Scanner(inStream2);

      double file1Avg = calcAvgInputVal(fileScnr1);
      double file2Avg = calcAvgInputVal(fileScnr2);

      return file2Avg / file1Avg;
   }

   public static void main(String[] args) {
      Scanner scnr = new Scanner(System.in);
      String file1;
      String file2;
      double avgSpeedup;
      boolean retry = true;

      while (retry) {
         System.out.print("Enter data file names: ");
```

```
            file1 = scnr.next();
            file2 = scnr.next();

            try {
               avgSpeedup = calcAvgSpeedup(file1, file2);
               retry = false;

               System.out.println("Speedup: " + avgSpeedup);
            }
            catch (FileNotFoundException exception) {
               System.out.println(exception.getMessage());
               retry = true;
            }
            catch (Exception exception) {
               System.out.println(exception.getMessage());
               retry = false;
            }
         }
      }
   }
```

Console

```
Enter data file names: times1.txt bad.txt
bad.txt (No such file or directory)
Enter data file names: times1.txt times2.txt
Speedup: 1.25

...

Enter data file names: times1.txt times3.txt
Negative number of values
```

times1.txt

```
3
1.0
2.0
3.0
```

times2.txt

```
4
1.0
2.0
3.0
4.0
```

times3.txt

```
-3
1.0
2.0
3.0
```

Conclusion

- The `throws` clause specifies the types of exceptions that a method may throw and callers of the method should handle.
- Java has two types of exceptions: **Checked** and **Unchecked** exceptions.
- Java's catch or specify requirement requires methods to either catch a checked exception using a `catch` block or specify that the method throws the checked exception using a `throws` clause.
- A method may call another method with a `throws` clause. If the calling method does not handle the exception types thrown by the called method, the calling method's `throws` clause must specify all exception types thrown by the called method.

User-defined exceptions

User-defined exception types can be used to handle specific exceptions in a program. A custom exception type can be defined by extending the Exception class. This approach allows the programmer to define exceptions with custom messages that are relevant to the program's context. Additionally, by defining custom exception types, the program can handle each exception separately, making the code more readable and efficient.

Limitations of using the Exception class

A catch block that catches the `Exception` type can catch exceptions of any type.

- Thus, a program that uses the `Exception` type may not be able to differentiate between caught exceptions or may catch unintended exception types.

Example: Density calculator with multiple user-defined exception types

The program below throws exceptions of type `InvalidNegativeInputException` for negative inputs and throws `NaNException` when dividing **0.0** by **0.0**.

By using separate exception handlers for each exception type, the program can handle each exception separately.

Class Definitions

`InvalidNegativeInputException.java` :

```
public class InvalidNegativeInputException extends Exception {
   public InvalidNegativeInputException(String varName) {
      super("Variable " + varName + " is negative");
   }
}
```

`NaNException.java` :

```
public class NaNException extends Exception {
   public NaNException(String varName) {
      super("Variable " + varName + " is NaN");
   }
}
```

`DensityCalculator.java` :

```
import java.util.Scanner;

public class DensityCalculator {
   public static double getPositiveValue(Scanner scnr, String valName)
                        throws InvalidNegativeInputException {

      System.out.print("Enter " + valName + ": ");

      double inputVal = scnr.nextDouble();

      if (inputVal < 0.0) {
          throw new InvalidNegativeInputException(valName);
      }

      return inputVal;
   }

   public static double getDensity(Scanner scnr)
                        throws InvalidNegativeInputException,
NaNException {

      double massVal = getPositiveValue(scnr, "massVal");
      double volumeVal = getPositiveValue(scnr, "volumeVal");
      double densityCalc = massVal / volumeVal;

      if (Double.isNaN(densityCalc)) {
         throw new NaNException("densityCalc");
      }

      return densityCalc;
   }

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

      try {
         System.out.println("Density: " + getDensity(scnr));
      }
      catch (InvalidNegativeInputException excpt) {
         System.out.println(excpt.getMessage());
         // Handle ...
      }
```

```
        catch (NaNException excpt) {
            System.out.println(excpt.getMessage());
            // Handle ...
        }
    }
}
```

Explanation

The `DensityCalculator` class defines two methods, `getPositiveValue` and `getDensity`, that throw exceptions of type `InvalidNegativeInputException` and `NaNException` when the input is negative or NaN, respectively. These exceptions are defined in the classes `InvalidNegativeInputException` and `NaNException`.

The `main` method uses try-catch blocks to handle exceptions thrown by `getDensity`. If an `InvalidNegativeInputException` is caught, the program prints the exception message, and if a `NaNException` is caught, the program also prints the exception message. By handling each exception separately, the program can provide more specific and informative error messages.

Conclusion

Custom exception types are a powerful tool that can be used to improve the readability and efficiency of programs. By defining custom exception types, the program can handle each exception separately, making the code more readable and efficient. Additionally, custom exception types can provide more specific and informative error messages that are relevant to the program's context, making it easier to identify and fix errors. It is important to note that custom exception types should be used judiciously and only when necessary to avoid overcomplicating the program's design.

Exceptions with Files

Handling exceptions from opening invalid files

- A program may try to open a file that does not exist.
    - *Ex:* The file may have been deleted, renamed, or moved.

- The `FileInputStream` constructor throws `FileNotFoundException` if the specified file cannot be found or opened for reading.

Closing Files

- A good practice is to close all files to allow the operating system to clean up any resources used while reading or writing a file.
- To close the files, the `Scanner` and `PrintWriter` objects should be initialized to `null` and closed in a try-catch block.
- The following code reads numbers from an input file, writes the average to an output file, and then closes both files before exiting.

Closing multiple files

```
import java.util.Scanner;
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.PrintWriter;
import java.io.FileNotFoundException;
import java.io.IOException;

public class FileDataAverage {
   public static void main(String[] args) {
      Scanner scnr = new Scanner(System.in);
      int expectedNumValues = 0;
      int numValuesRead = 0;
      int valueSum = 0;
      double valueAvg = 0.0;

      FileInputStream fileInStream;
      Scanner fileScanner = null;
      FileOutputStream fileOutStream;
      PrintWriter fileWriter = null;

      try {
         // Open input file.
         fileInStream = new FileInputStream("input.txt");
         fileScanner = new Scanner(fileInStream);
         System.out.println("Opened input.txt");

         // Open output file.
         fileOutStream = new FileOutputStream("output.txt");
         fileWriter = new PrintWriter(fileOutStream);
         System.out.println("Opened output.txt");

         // The first entry in the input file is the expected number of
values.
         expectedNumValues = fileScanner.nextInt(); // May throw
InputMismatchException

         // Calculate the average input value.
         for (numValuesRead = 0; numValuesRead < expectedNumValues;
++numValuesRead) {
            valueSum += fileScanner.nextInt();  // May throw
InputMismatchException
```

```
            }

            valueAvg = valueSum / numValuesRead;

            // Print the average to the output file.
            fileWriter.println("Average: " + valueAvg);
         }
         catch (FileNotFoundException exception) {
            System.out.println("Error opening file");
         }

         // Close both files.
         if (fileScanner != null) {
            fileScanner.close();
            System.out.println("Closed input.txt");
         }

         if (fileWriter != null) {
            fileWriter.close();
            System.out.println("Closed output.txt");
         }
      }
   }
```

Closing files with the try-with-resources statement

- A program can use a try-with-resources statement to automatically close files if any exception, caught or uncaught, occurs within a try block.
- The **try-with-resources** statement declares closable resources, like files, within parentheses after the try keyword and before the try's opening curly brace.
- The declared resources are closed after the try block exits.
- Multiple resources, separated by semicolons, can be declared in a single try-with-resources statement.

```
try (FileInputStream inStrm = new FileInputStream(fName);
    Scanner scnr = new Scanner(inStrm)) {
    // ...
}
catch (FileNotFoundException e) {
    // ...
}
catch (IOException e) {
    // ...
}
```

finally block

- A `finally` block always executes when a try block exits.
- A programmer can use a `finally` block to do additional processing, even if an exception is thrown in the try statement.
- The program below uses a `finally` block to write partial results to the output file, even if an `InputMismatchException` exception occurs while reading the input file.

```
import java.util.Scanner;
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.PrintWriter;
import java.io.FileNotFoundException;

public class FileDataSum {
   public static void main(String[] args) {
      Scanner scnr = new Scanner(System.in);
      PrintWriter fileWriter = null;
      int numValues;
      int numValuesRead = 0;
      int valueSum = 0;

      try (Scanner fileScnr = new Scanner(new
FileInputStream("input.txt"))) {
         fileWriter = new PrintWriter(new
FileOutputStream("output.txt"));
         numValues = fileScnr.nextInt();

         for (numValuesRead = 0; numValuesRead < numValues;
++numValuesRead) {
            valueSum += fileScnr.nextInt();
         }
      }
      catch (FileNotFoundException exception) {
         System.out.println("File not found");
      }
      finally {
         if (fileWriter != null) {
            fileWriter.println(valueSum);
            fileWriter.close();
         }
      }
   }
}
```

Conclusion

- It is important to handle exceptions when working with files to prevent the program from crashing.

- A good practice is to close all files after finishing working with them to allow the operating system to clean up any resources used while reading or writing a file.
- The try-with-resources statement can be used to automatically close files if any exception occurs within a try block.
- The finally block always executes when a try block exits and can be used to do additional processing, even if an exception is thrown in the try statement.