Exception Handling

Handling Errors During the Program Execution

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Table of Contents

What Are Exceptions?

Notifications about Failed Operations

What Are Exceptions?

- **Exceptions** handle **errors** and **problems** at runtime
- **Throw** an exception to **signal** about a problem

```
if (size < 0)
   throw new Exception("Size cannot be
negative!");
```

- **Catch** an exception to **handle** the problem

```
try {
   size = Integer.ParseInt(text);
} catch (Exception ex) {
   System.out.println("Invalid size!");
}
```

More About Exceptions

- **Exceptions** occur when the normal flow of the program is interrupted due to a problem (or error)
  - When an operation **fails to execute** at runtime
  - **Example**: trying to read a non-existing file
- **Exceptions** allow problematic situations to be **handled** at multiple levels
  - Simplify code construction and maintenance
- **Exception objects** hold detailed information about the error: **error message**, **stack trace**, etc.

Unhandled Exception with Stack Trace

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```
int x = Integer.parseInt("invalid number");
```

Error message

```
"C:\Program Files\Java\jdk-17.0.1\bin\java.exe" "-javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Communi
Exception in thread "main" java.lang.NumberFormatException Create breakpoint : For input string: "invalid number"
    at java.base/java.lang.NumberFormatException.forInputString(NumberFormatException.java:67)
    at java.base/java.lang.Integer.parseInt(Integer.java:668)
    at java.base/java.lang.Integer.parseInt(Integer.java:786)
    at ExceptionExample.main(ExceptionExample.java:5)
```

Stack trace

The Throwable Class

- Exceptions in Java are **objects**
- The `Throwable` class is a base for all Java exceptions
  - Contains information for the cause of the problem
  - `Message` – a text description of the exception
  - `StackTrace` – the snapshot of the "call stack" at the moment when the exception is throws

Types of Exceptions in Java

- All Java exceptions inherit from `java.lang.Throwable`
- Direct descendants of `Throwable`:
  - `Error` – not expected to be caught from the program under normal circumstances
    - Examples: `StackOverflowError`, `OutOfMemoryError`
  - `Exception`
    - Used for exceptional conditions that user programs could catch
    - Examples: `ArithmeticException`, `IOException`

Exceptions

- **Exceptions** are two types:
  - **Checked** – an exceptions that should be obligatory handled checked by the compiler during the compilation
    - Also called **compile-time** exceptions

```
public static void main(String args[]) {
  File file = new File("non-existing-file.txt");
  FileReader fr = new FileReader(file);
}
```

FileNotFoundException

  - **Unchecked** – exceptions that occur at the time of execution
    - Also called **runtime exceptions**, not obligatory handled

Exception Hierarchy in Java

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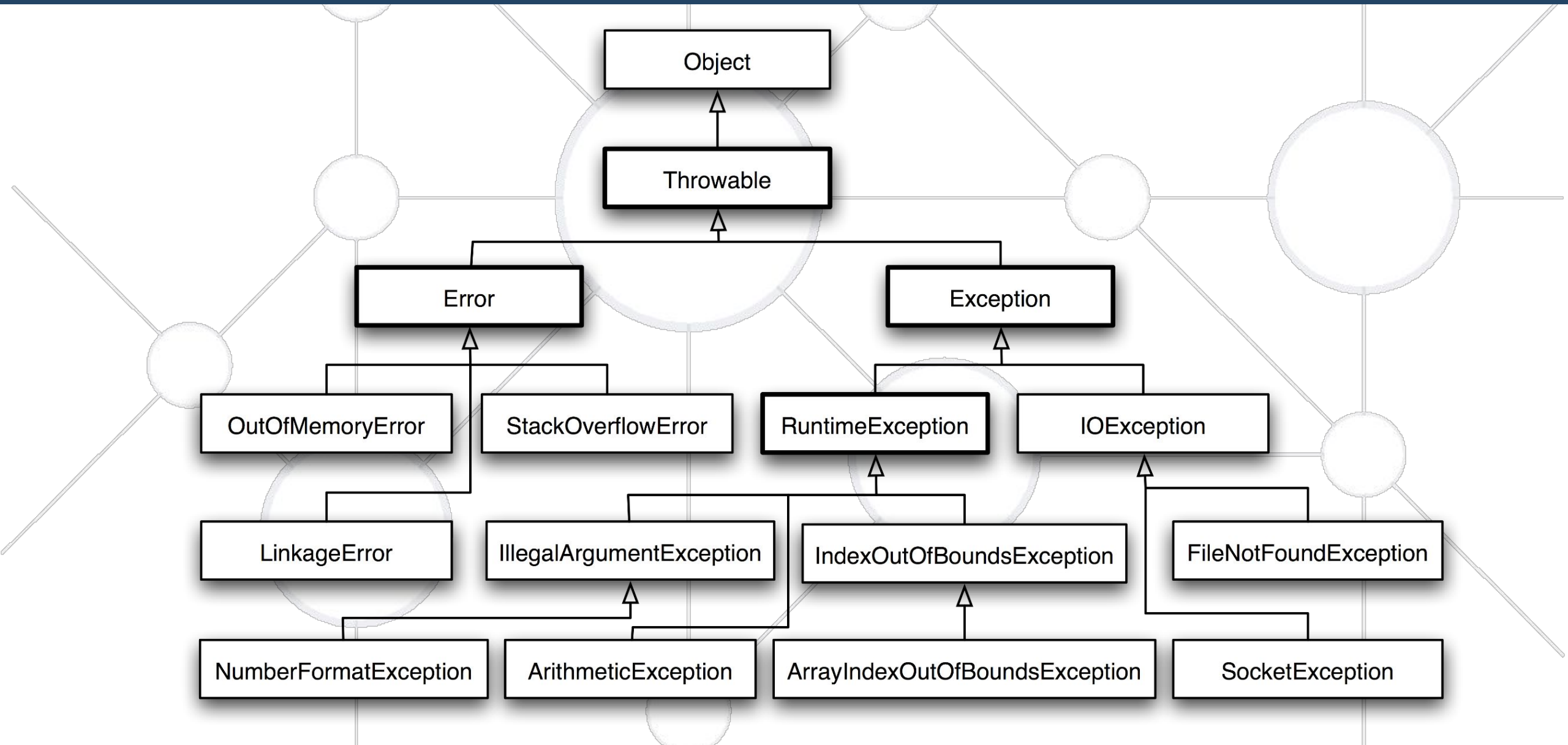

Handling Exceptions

Using `try-catch-finally`

How Do Exceptions Work?

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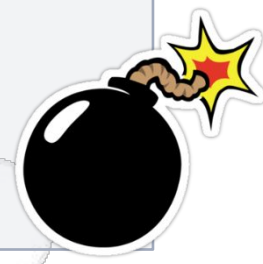
try	Try to run this code
catch	Run this code when there is an exception
finally	Always run this code

Handling Exceptions

- In Java exceptions can be handled by the `try-catch` construction

```
try {
   // Do some work that can raise an exception
} catch (SomeException) {
   // Handle the caught exception
}
```



- `catch` blocks can be used multiple times to process different exception types

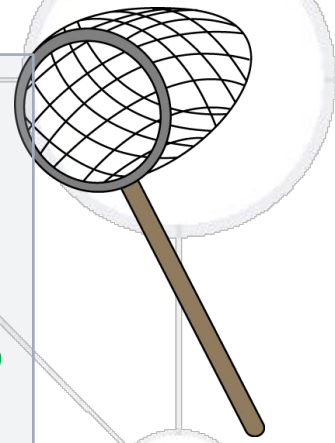
Using try-catch – Example

```
Scanner scanner = new Scanner(System.in);
String s = scanner.nextLine();
try {
   Integer.parseInt(s);
   System.out.printf(
      "You entered a valid integer number: %s", s);
} catch (NumberFormatException ex) {
   System.out.println("Invalid integer number!");
}
```

Handling Exceptions

- When **catching an exception** of a particular class, all its **descendants** (child exceptions) are caught too, e.g.

```
try {
  // Do some work that can cause an exception
} catch (IndexOutOfBoundsException iobEx) {
  // Handle the caught out-of-bounds exception
}
```



- Handles **IndexOutOfBoundsException** and its descendants **ArrayIndexOutOfBoundsException** and **StringIndexOutOfBoundsException**

Find the Mistake!

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```
String str = scanner.nextLine();

try {
    Integer.parseInt(str);
} catch (Exception ex) {
    System.out.println("Cannot parse the number!");
} catch (NumberFormatException ex) {
    System.out.println("Invalid integer number!");
}
```

Should be last

Unreachable code

Problem: Number in Range

- Write a program to **enter an integer** in a **certain range**, e. g. 10-20
  - Read a **range** (two integers **start** <= **end**) and print the range
  - When an invalid number is entered or the number is out of range, print "**`Invalid number: {num}`**" and enter a number again
  - When the entered number is valid, print "**`Valid number: {num}`**"

```
10 20
5
xx
20
```

```
Range: [10...20]
Invalid number: 5
Invalid number: xx
Valid number: 20
```

```
-5 50
hi
-6
-1
```

```
Range: [-5...50]
Invalid number: hi
Invalid number: -6
Valid number: -1
```

Solution: Number in Range

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```
private static int readNumberInRange(
    Scanner scanner, int start, int end) {
  while (true) {
    String line = scanner.nextLine();
    try {
      int num = Integer.parseInt(line);
      if (num >= start && num <= end)
        return num; // Valid number (in range)
    } catch (Exception ex) {
      // Parse failed --> invalid number
    }
    System.out.println("Invalid number: " + line);
  }
}
```

Solution: Number in Range (2)

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

  String[] range = scanner.nextLine().split(" ");
  int start = Integer.parseInt(range[0]);
  int end = Integer.parseInt(range[1]);
  System.out.printf("Range: [%d...%d]\n", start, end);

  int num = readNumberInRange(scanner, start, end);
  System.out.println("Valid number: " + num);
}
```

Submit your solution to the judge: https://judge.softuni.org/Contests/Practice/Index/3294#50

Try-Finally

Executing a Cleanup Code in All Cases

The try-finally Statement

- The statement:

```
try {
    // Do some work that can cause an exception
} finally {
    // This block will always execute
}
```

- Ensures execution of a given block in all cases
  - When an **exception** is raised or **not** in the `try` block
- Used for execution of **cleaning-up code**, e.g. releasing resources

Try-finally – Example

```
static void tryFinallyExample() {
  System.out.println("Code executed before try-finally.");
  try {
     String str = scanner.nextLine();
     Integer.parseInt(str);
     System.out.println("Parsing was successful.");
     return; // Exit from the current method □ executes the "finally" block
  } catch (NumberFormatException ex) {
     System.out.println("Parsing failed!");
  } finally {
     System.out.println("This cleanup code is always executed.");
  }
  System.out.println("This code is after the try-finally block.");
}
```

Throwing Exceptions

Using the "**throw**" Keyword

Using Throw Keyword

- **Throwing** an exception with an error message:

```
throw new IllegalArgumentException("Invalid amount!");
```

- Exceptions can accept **message** and **cause** (nested exception):

```
try {
  …
} catch (SQLException sqlEx) {
  throw new IllegalStateException("Cannot save invoice", sqlEx);
}
```

- **Note**: if the original exception is not passed, the initial cause of the exception is lost

Throwing Exceptions

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- Exceptions are **thrown** (raised) by the `throw` keyword
- Used to **notify the calling code** in case of an error or unusual situation
- When an exception is thrown:
  - The program execution **stops immediately**
  - The exception **travels over the stack**
    - Until a matching `catch` block is reached to handle it
- **Unhandled exceptions** display an error message

Re-Throwing Exceptions

- Caught exceptions can be **re-thrown** again:

```
try {
    Integer.parseInt(str);
} catch (NumberFormatException ex) {
    System.out.println("Parse failed!");
    throw ex; // Re-throw the caught exception
}
```

Throwing Exceptions – Example

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```
public static double calcSqrt(double value) {
  if (value < 0)
    throw new ArithmeticException(
      "Sqrt for negative numbers is undefined!");
  return Math.sqrt(value);
}
public static void main(String[] args) {
  try {
    calcSqrt(-1);
  } catch (ArithmeticException ex) {
    System.err.println("Error: " + ex.getMessage());
    ex.printStackTrace();
  }
}
```

Problem: Square Root

- Write a program that **reads an integer** number and calculates and prints its **square root** (with 2 digits after the decimal point)
  - If the number is **invalid** or **negative**, print "**Invalid**"
- In all cases finally print "**Goodbye**"
- Use **try-catch-finally**

9	→	3.00 Goodbye	20	→	4.47 Goodbye
-5	→	Invalid Goodbye	xx	→	Invalid Goodbye

Solution: Square Root

```
Scanner scanner = new Scanner(System.in);
try {
  int num = Integer.parseInt(scanner.nextLine());
  double sqrt = calcSqrt(num);
  System.out.printf("%.2f\n", sqrt);
} catch (Exception ex) {
  System.out.println("Invalid");
}
finally {
  System.out.println("Goodbye");
}
```

Submit your solution to the judge: https://judge.softuni.org/Contests/Practice/Index/3294#51

The "throws" in Method Declarations

Forcing Invokers to Handle Certain Exceptions

Using "throws" in Method Declaration

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```
static String readTextFile(String fName) throws IOException {
  BufferedReader reader =
    new BufferedReader(new FileReader(fName));
  StringBuilder result = new StringBuilder();
  try {
    String line;
    while ((line = reader.readLine()) != null)
      result.append(line + System.lineSeparator());
  } finally {
    reader.close();
  }
  return result.toString();
}
```

Invoking Method Declared with "throws"

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```
public static void main(String[] args) {
  String fileName = "./src/TextFileReader.java";
  try {
    String sourceCode = readTextFile(fileName);
    System.out.println(sourceCode);
  } catch (IOException ioex) {
    System.err.println("Cannot read file: " + fileName);
    ioex.printStackTrace();
  }
}
```

Catching IOException is obligatory!

Throwing from the Main Method

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- The `main()` method can declare as "**throws**" all exception classes, which it refuses to handle

```
public static void main(String[] args)
    throws IOException {
  FileWriter file = new FileWriter("example.txt");
  file.write("Some text in the file");
  file.close();
}
```

Custom Exceptions

Declaring Your Own Exception Class

Creating Custom Exceptions

- Custom exceptions inherit an exception class (commonly – **Exception**)

```
public class FileParseException extends Exception {
  private int lineNum;

  public FileParseException(String msg, int lineNum) {
    super(msg + " (at line " + lineNum +")");
    this.lineNum = lineNum;
  }

  public int getLineNum() { return lineNum; }
}
```

Using Custom Exceptions

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- **Throw** your exceptions like any other:

```
throw new FileParseException(
  "Cannot read setting", 75);
```

```
"C:\Program Files\Java\jdk-17.0.1\bin\java.exe" "-javaagent:C:\Program Files\JetBrains
Exception in thread "main" FileParseException: Cannot read setting (at line 75)
    at CustomExceptionsExample.main(CustomExceptionsExample.java:3)
```

- If your exception derives from **Exception** → handle it obligatory
- If it derives from **RuntimeException** → handle it optionally

Best Practices

Working with Exceptions the Right Way

Using The Catch Block

- The `catch` blocks should:
  - Begin with the exceptions **lowest** in the hierarchy
  - Continue with the more general exceptions
  - Otherwise, a **compilation error** will occur
- Each `catch` block should handle only these exceptions, which it expects
  - If a method is not competent to handle an exception, it should leave it unhandled
  - Handling all exceptions disregarding their type is a popular **bad practice** (anti-pattern)!

Common Exception Types in Java (1)

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- When an application attempts to use `null` in a case where an object is required: `NullPointerException`
- A method has been passed an illegal or inappropriate argument: `IllegalArgumentException`
- An array has been accessed with an illegal index: `ArrayIndexOutOfBoundsException`
- An index is either negative or greater than the size of the string: `StringIndexOutOfBoundsException`

Common Exception Types in Java (2)

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- Attempt to convert an inappropriate string to a numeric type: `NumberFormatException`
- When an exceptional arithmetic condition has occurred: `ArithmeticException`
- Attempt to cast an object to a subclass of which it is not an instance: `ClassCastException`
- When a file or network or other input / output operation has failed: `IOException`

Exceptions – Best Practices (1)

- When throwing an exception, always pass to the constructor a **good explanation message**
  - The **error message** should make obvious what the problem is
  - The exception message should explain **what causes the problem** (and give directions **how to solve it**)
    - **Good**: "Size should be integer in range [1…15]"
    - **Good**: "Invalid state. First call Initialize()"
    - **Bad**: "Unexpected error"
    - **Bad**: "Invalid argument"

Exceptions – Best Practices (2)

- Exceptions can decrease the application **performance**
  - Throw exceptions only in situations which are really exceptional and should be handled
  - Do not throw exceptions in the normal program control flow
  - The JVM could throw exceptions at any time with no way to predict them
    - E. g. `StackOverflowError` or `OutOfMemoryError`

Summary

- **Exceptions** provide a **flexible** error handling mechanism
- **Try-catch** allows exceptions to be handled
- **Unhandled exceptions** crash with an error message
- **Try-finally** ensures a given code block is always executed

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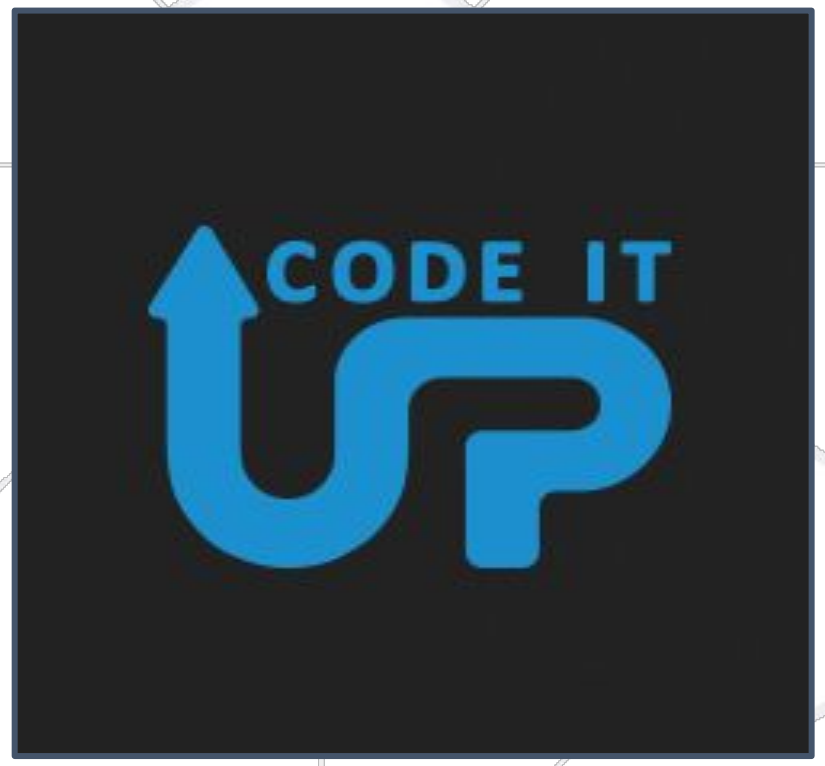

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