Java IOs - Course material

https://github.com/heig-vd-dai-course

Markdown · PDF

L. Delafontaine and H. Louis, with the help of GitHub Copilot.

Based on the original course by O. Liechti and J. Ehrensberger.

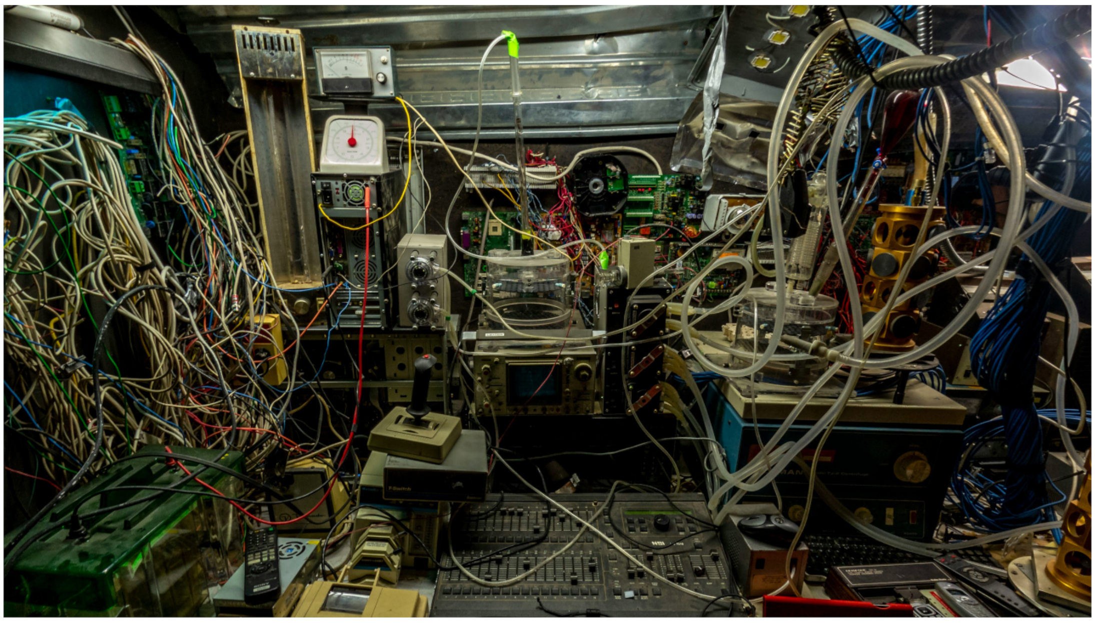


Table of contents

- Table of contents
- Objectives
- Prepare and setup your environment
    - Check and run the code examples
- Sources, streams and sinks of data
- The Java IO API
- Types of data
- Processing binary data with the Java IO API
    - Reading binary data
    - Writing binary data
    - Reading and writing binary data with buffers
    - A quick note on little endian vs. big endian
- Processing text data with the Java IO API
    - Ancestor of character representations: ASCII
    - Extended ASCII: codes pages
    - Unicode
    - UTF-8
    - What happens if you ignore the character encoding?
    - Reading and writing text data
    - End of line characters
    - Dealing with errors
- When to use which IO?
- Common pitfalls
- Practical content
    - Create and clone the repository
    - Implement the different types of streams
    - Compare the results
    - Share your results
    - Go further
- Conclusion
    - What did you do and learn?
    - Test your knowledge
- Finished? Was it easy? Was it hard?
- What will you do next?

- Additional resources
- Solution
- Sources

Objectives

This chapter will help you understand why IOs are important in network programming and how to use them in Java.

Network programming is about reading and writing data (= files) from and to the network. Files are a great example to understand how IOs work in the first place without the hassle of network programming.

You might need to use different types of IOs depending on the type of data you want to process. You will learn how to use the right IOs for the right data.

As this chapter is quite abstract, you will first setup your environment to be able to run some code examples along with the theory.

These skills are essential to be able to process data from the network later on this course!

Let's get started!

Prepare and setup your environment

Check and run the code examples

In this section, you will clone the code examples repository to check and run the code examples along with the theory.

Clone the repository

Clone the heig-vd-dai-course/heig-vd-dai-course-code-examples repository to get the code examples.

Access the code examples in your terminal

Open a terminal and navigate to the `heig-vd-dai-course-code-examples` directory.

As a quick reminder, these commands can help you to navigate in the terminal:

- `ls` to list the files and directories in the current directory
- `cd directory` to navigate to the `directory` directory
- `cd ..` to navigate to the parent directory
- `pwd` to print the current directory
- `clear` to clear the terminal
- `exit` to exit the terminal

Explore and run the code examples

In the `05-java-ios` directory, check out the `README.md` file to learn how to run the code examples.

As a quick reminder, you can run the code examples using the following command:

```
# Compile the code example
javac HelloWorld.java

# Run the code example
java HelloWorld
```

You now have everything you need to run the code examples. Let's dive into the theory!

Sources, streams and sinks of data

Whenever you deal with data, you need to read data from a source and write it to a destination.

An abstraction of this process is called **sources, streams and sinks of data**.

A **stream** is a way to read or write data from a **source** to a **sink**.

A **source of data** is **where the data comes from**. It can be a file, a network connection, a keyboard, etc. A common term for a source of data is something that **produces** data (**a producer**).

A **sink of data** is **where the data goes**. It can be another file, a network connection, a screen, etc. A common term for a sink of data is something that **consumes** data (**a consumer**).

A **stream** is **a way to read or write data** from a source to a sink.

The Java IO API

The Java documentation is separated in modules. The Java IO API is part of the `java.base` module.

In the `java.base` module, there are two main packages to read and write data:

- `java.io`: the standard Java IO API
- `java.nio`: the Java NIO API

The `java.io` package is called **Java IO API** or the **standard Java IO API**.

The **Java NIO API** was introduced in Java 1.4. It is a more modern API that can be more efficient and more flexible than the Java IO API in some use-case. It is also more complex to use and is meant for more advanced use cases (writing scalable servers for example). We will not cover this API in this course.

Types of data

When you deal with data, you need to know what type of data you are dealing with.

There are two main types of data:

- **Binary data**: data that is stored as bytes. This is the most basic type of data. It is used to store files, images, videos, etc.
- **Text data**: data that is stored as characters. This is a more complex type of data. It is used to store text files, configuration files, etc.

What differentiates binary data from text data is how the data is interpreted:

- **Binary data**: the data is read or written as bytes. You do not have to interpret the bytes, you just use them as they are.
- **Text data**: the data is read or written as characters. You have to interpret the bytes to get the characters.

When you read or write data, you need to know what type of data you are dealing with to use the right tools to read or write the data.

Processing binary data with the Java IO API

Binary data processing is the most basic type of data processing:

1. You open a file
2. You read/write/modify the bytes as they are (e.g. copy to another file).
3. You close the file

You do not have to interpret the bytes, you just use them as they are.

Reading binary data

When you read binary data, you read the bytes as they are stored in the file.

The most simple way to read binary data is byte by byte.

This is done using the InputStream class. The InputStream class is an abstract class that is the superclass of all classes representing an input stream of bytes (e.g. FileInputStream).

Open the BinaryReadFileExample.java file in the 05-java-ios directory to see how to read binary data byte by byte.

The following line opens a file for reading binary data. It will attempt to open the file binary-file.bin in the current directory:

```
InputStream fis = new FileInputStream("binary-file.bin");
```

As this file is not yet created, the program will throw a FileNotFoundException exception if you try to execute the program. This is normal. You will create this file and run the program later.

The following line reads data from the file byte by byte:

```
// -1 indicates the end of the file
int b;
while ((b = fis.read()) != -1) {
  System.out.print(b);
}
```

Each read() call will read one byte from the file. The read() method returns the byte read as an int. If the end of the file is reached, the read() method will return -1.

The following line closes the file:

```
fis.close();
```

This is important to close the file after you have read the data. If you do not close the file, you might lose data or corrupt the file as other processes might not be able to access the file.

Compile and execute the BinaryReadFileExample.java file. This will throw a FileNotFoundException exception as the file binary-file.bin does not yet exist.

Continue to the next section to see how to create this file.

Writing binary data

When you write binary data, you write the bytes as they are stored in the file.

The most simple way to write binary data is byte by byte.

This is done using the OutputStream class. The OutputStream class is an abstract class that is the superclass of all classes representing an output stream of bytes.

Open the BinaryWriteFileExample.java file in the 05-java-ios directory to see how to write binary data byte by byte.

The following line opens a file for writing binary data. It will attempt to open the file binary-file.bin in the current directory:

```
OutputStream fos = new FileOutputStream("binary-file.bin");
```

The following line writes data to the file byte by byte:

```
for (int i = 0; i < 256; i++) {
  fos.write(i);
}
```

Each write() call will write one byte to the file.

The following line closes the file:

```
fis.close();
```

This is important to close the file after you have read the data. If you do not close the file, you might lose data or corrupt the file as other processes might not be able to access the file.

Compile and execute the BinaryWriteFileExample.java file. This will create the file binary-file.bin in the current directory.

Compile and execute the BinaryReadFileExample.java file. This will read the content of the file binary-file.bin and print the file content to the console.

Reading and writing binary data with buffers

When you read or write binary data byte by byte, each read() or write() call will issue a system call to read or write one byte from or to the file. This is not efficient.

To improve the performance, you can (and should) use a buffer. Instead of reading one byte at a time, you can read a block of bytes at a time:

- When reading for the first time, a system call is made and the data read is stored in the buffer.
- Then, as long as the buffer is not empty, we read from it (no system call).
- As soon as the buffer is empty, a new system call is made and the process is repeated.

The same applies when writing data:

- When writing for the first time, a system call is made and a buffer is created to store the data.
- Then, as long as the buffer is not full, we write to it (no system call).
- As soon as the buffer is full, its content is written to the file and the buffer is emptied and the process is repeated.
- When closing the file, the remaining data in the buffer is written to the file.

This is done using the BufferedInputStream and BufferedOutputStream classes.

The BufferedInputStream class is a subclass of the InputStream class that adds buffering to the input stream. The BufferedOutputStream class is a subclass of the OutputStream class that adds buffering to the output stream.

Open the BinaryBufferReadFileExample.java file in the 05-java-ios directory to see how to read binary data with buffers.

Here are the changes between the BinaryReadFileExample.java file and the BinaryBufferReadFileExample.java file:

```
  public static void main(String[] args) throws IOException {
    InputStream fis = new FileInputStream("binary-file.bin");
+   BufferedInputStream bis = new BufferedInputStream(fis);

    // -1 indicates the end of the file
    int b;
-   while ((b = fis.read()) != -1) {
+   while ((b = bis.read()) != -1) {
      System.out.print(b);
    }

-   fis.close();
+   // Closing the BufferedInputStream automatically closes the FileInputStream
+   bis.close();
  }
```

The BufferedInputStream class is created with the FileInputStream class as an argument. The BufferedInputStream class will read data from the FileInputStream class and store it in a buffer.

The BufferedInputStream class will read data from the buffer instead of reading data from the file directly. This is more efficient as the buffer can store more data than the FileInputStream class can read in one system call.

Compile and execute the BinaryBufferReadFileExample.java file. This will read the content of the file binary-file.bin and print the file content to the console.

Open the BinaryBufferWriteFileExample.java file in the 05-java-ios directory to see how to write binary data with buffers.

Here are the changes between the BinaryWriteFileExample.java file and the BinaryBufferWriteFileExample.java file:

```
   public static void main(String[] args) throws IOException {
     OutputStream fos = new FileOutputStream("binary-file.bin");
+    BufferedOutputStream bos = new BufferedOutputStream(fos);

     for (int i = 0; i < 256; i++) {
-      fos.write(i);
+      bos.write(i);
     }

-    fos.close();
+    // Flush the buffer to write the remaining bytes
+    bos.flush();
+    bos.close();
   }
```

The BufferedOutputStream class is created with the FileOutputStream class as an argument. The BufferedOutputStream class will write data to the FileOutputStream class and store it in a buffer.

The BufferedOutputStream class will write data to the buffer instead of writing data to the file directly. This is more efficient as the buffer can store more data than the FileOutputStream class can write in one system call.

The flush() method is called to write the remaining bytes in the buffer to the file. The flush() method is automatically called when the close() method is called.

We recommend calling the flush() method before calling the close() method anyway to ensure that all data is written to the file just in case you do some other operations before effectively closing the file.

Compile and execute the BinaryBufferWriteFileExample.java file. This will create the file binary-file.bin in the current directory.

Compile and execute the BinaryBufferReadFileExample.java file. This will read the content of the file binary-file.bin and print the file content to the console.

A quick note on little endian vs. big endian

When working with binary data, you need to know if the data is encoded in **little endian** or in **big endian**.

Little endian means that the least significant byte is stored first. **Big endian** means that the most significant byte is stored first.

For example, the number `0x12345678` is stored as `0x78 0x56 0x34 0x12` in little endian and as `0x12 0x34 0x56 0x78` in big endian.

This is important to know when you read or write binary data. If you read or write binary data in the wrong endian, the data will be corrupted.

Java uses big endian by default. You can use little endian by using the `ByteBuffer` class. We will not cover this in this course.

Processing text data with the Java IO API

While binary data processing is quite simple, text data processing is more complex.

When you read text data, you need to interpret the bytes to get the characters.

When you write text data, you need to encode the characters to bytes.

To better understand text data processing, you need to understand character encodings.

Ancestor of character representations: ASCII

The **American Standard Code for Information Interchange (ASCII)** is one of the first character encodings. It is a character encoding that maps 128 binary values to 128 characters. For example, the binary data `01000001` is mapped to the character `A`.

The first implementation of ASCII was published in 1963. It was meant to be used for the English language only. It was later extended to support other languages.

Extended ASCII: codes pages

As ASCII is a very limited character encoding (only 8 bits, leaving 128 other possible values), many other character encodings were created to support more characters and languages.

These extended ASCII character encodings are called **code pages**. They were then standardized by the **International Organization for Standardization (ISO)**.

Common code pages are **ISO-8859-1** (also called **Latin-1**), **ISO-8859-15** (also called **Latin-9**), **Windows-1252** (also called **CP1252**), etc.

Unicode

Unicode is a newer character encoding standard that was meant to **solve the issues of ASCII and code pages** that could not support all specificities of all languages:

- Languages with more than 256 characters (like Chinese)
- Languages with more than one alphabet (like Serbian)
- Languages with more than one writing system (like Chinese or Japanese)

The Unicode specification defines 1,112,064 characters.

This is enough to **support all languages in the world** as well as emojis (for our greatest pleasure…).

Implementations of the Unicode standard are called **Unicode Transformation Formats (UTF)**. The most common implementations is **UTF-8**.

UTF-8

UTF-8 is a variable-length character encoding that uses 1 to 4 bytes to encode a character. It is the most common implementation of the Unicode standard. It is the default character encoding on the Internet and many other applications.

UTF-8 is backward compatible with ASCII. This means that if you have a file encoded in ASCII, it is also encoded in UTF-8.

The following table shows how a character is encoded in UTF-8 depending on the number of bytes used:

Binary data	**Meaning**
0xxxxxxx	1 byte character
110xxxxx 10xxxxxx	2 bytes character
1110xxxx 10xxxxxx 10xxxxxx	3 bytes character
11110xxx 10xxxxxx 10xxxxxx 10xxxxxx	4 bytes character

As some bits are used to encode the length of the character, the number of possible characters is limited, hence the 1,112,064 characters limit.

Other implementations of the Unicode standard exist, such as UTF-16 and UTF-32. They are not as common as UTF-8 and are not backward compatible with ASCII.

Java strings for instance uses UTF-16, meaning a character is encoded in 2 bytes (in C/C++, a character is encoded in 1 byte).

What happens if you ignore the character encoding?

When you open a file, you need to know the character encoding that was used to encode the file.

The character encoding is not usually stored in the file. You need to know it in advance to be able to read the file correctly.

When the character encoding is not known in advance or misinterpreted, it can lead to issues like displaying the wrong characters or not being able to display the characters at all.

A good example is when you open a text file encoded in UTF-8 with a text editor that does not support UTF-8. The text editor will try to interpret the file as ASCII and will display the wrong characters (`Ã©` instead of `é` for example).

Open the `TextCharacterEncodingsExample.java` file in the `05-java-ios` directory to see how to encode and decode characters with different character encodings.

Compile and execute the `TextCharacterEncodingsExample.java` file. This will print the word "student" encoded in different character encodings for different languages.

Notice that the word "student" is encoded in different ways depending on the character encoding used. This is because the character encoding defines how the characters are encoded in bytes.

If you do not set the character encoding when you read or write text data, the default character encoding will be used. This is not what you want as the file might be encoded in a different character encoding and all systems might not be able to read the file correctly.

Reading and writing text data

When you read and write text data, you need to know the character encoding used to encode the text data.

This is done using the Reader and Writer classes:

- The Reader class is an abstract class that is the superclass of all classes representing an input stream of characters (e.g. FileReader).
- The Writer class is an abstract class that is the superclass of all classes representing an output stream of characters (e.g. FileWriter).

Open the TextReadAndWriteFileExample.java file in the 05-java-ios directory to see how to read and write text data.

The following line opens a file for reading text data. It will attempt to open the file TextReadAndWriteFileExample.java (the current file) in the current directory:

```
Reader reader = new FileReader("TextReadAndWriteFileExample.java",
                StandardCharsets.UTF_8);
```

Notice that the character encoding is set to UTF-8. This is important to set the character encoding when you read or write text data. If you do not set the character encoding, the default character encoding will be used, which is not what you want as it can differ from other systems.

The following line opens a file for writing text data. It will attempt to open the file TextReadAndWriteFileExample.txt in the current directory:

```
Writer writer = new FileWriter("TextReadAndWriteFileExample.txt",
                StandardCharsets.UTF_8);
```

The following line reads data from the file byte by byte and writes it to the output file:

```
// -1 indicates the end of the file
int c;
while ((c = reader.read()) != -1) {
  writer.write(c);
}
```

Just as with binary data, each character is read and written byte by byte.

The following line closes the file:

```
writer.close();
reader.close();
```

Just as with binary data, reading and writing text data byte by byte is not efficient. You can use a buffer to read and write text data more efficiently.

Open the TextBufferReadAndWriteFileExample.java file in the 05-java-ios directory to see how to read and write text data with buffers.

Here are the changes between the TextReadAndWriteFileExample.java file and the TextBufferReadAndWriteFileExample.java file:

```
  public static void main(String[] args) throws IOException {
    Reader reader = new FileReader("TextReadAndWriteFileExample.java",
             StandardCharsets.UTF_8);
+   BufferedReader br = new BufferedReader(reader);
+
    Writer writer = new FileWriter("TextReadAndWriteFileExample.txt",
             StandardCharsets.UTF_8);
+   BufferedWriter bw = new BufferedWriter(writer);

    // -1 indicates the end of the file
    int c;
-   while ((c = reader.read()) != -1) {
-     writer.write(c);
+   while ((c = br.read()) != -1) {
+     bw.write(c);
    }

-   writer.close();
-   reader.close();
+   // Flush the buffer to write the remaining bytes
+   bw.flush();
+   bw.close();
+   br.close();
  }
```

The BufferedReader class is created with the FileReader class as an argument. The BufferedReader class will read data from the FileReader class and store it in a buffer.

The BufferedReader class will read data from the buffer instead of reading data from the file directly. This is more efficient as the buffer can store more data than the FileReader class can read in one system call.

The BufferedWriter class is created with the FileWriter class as an argument. The BufferedWriter class will write data to the FileWriter class and store it in a buffer.

The BufferedWriter class will write data to the buffer instead of writing data to the file directly. This is more efficient as the buffer can store more data than the FileWriter class can write in one system call.

The flush() method is called to write the remaining bytes in the buffer to the file. This is important to call the flush() method to make sure that all data is written to the file.

Compile and execute the TextBufferReadAndWriteFileExample.java file. This will read the content of the file TextReadAndWriteFileExample.java and write the file content to the file TextReadAndWriteFileExample.txt.

End of line characters

Another important thing to know when dealing with text files is the **end of line character**.

The end of line character is a special character that marks the end of a line.

There are different end of line characters depending on the operating system:

- Unix/Linux/macOS: '\n', called *"Line feed"* (LF)
- Windows: '\r\n', called *"Carriage Return + Line feed"* (CR+LF)

When you read a text file line by line, the string you get will **not** contain the end of line character(s).

When you write a string to a file, you have to add the end of line character(s) yourself if you want to write a new line.

Open the TextEndOfLineCharactersExample.java file in the 05-java-ios directory to see how to read and write text data with end of line characters.

The following line opens a file for writing text data. It will attempt to open the file TextEndOfLineCharactersExample.java (the current file) in the current directory:

```
InputStream is = new FileInputStream("TextEndOfLineCharactersExample.java");
Reader reader = new InputStreamReader(is, StandardCharsets.UTF_8);
BufferedReader br = new BufferedReader(reader);
```

Notice that this time, it opens the input file using a FileInputStream class as binary data. It then uses the class InputStreamReader to decode the binary data to text data using the UTF-8 character encoding. And finally, it uses the BufferedReader class to read the text data with buffers.

The following line opens a file for writing text data. It will attempt to open the file TextEndOfLineCharactersExample.txt in the current directory:

```
OutputStream os = new FileOutputStream("LineEndingsExample.txt");
Writer writer = new OutputStreamWriter(os, StandardCharsets.UTF_8);
BufferedWriter bw = new BufferedWriter(writer);
```

Notice that this time, it opens the output file using a FileOutputStream class as binary data. It then uses th class OutputStreamWriter to write the file with the UTF-8 character encoding. And finally, it uses a BufferedWriter class to write the binary data with buffers.

The following line reads data from the file line by line and writes it to the output file with the end of line character:

```
String line;
while ((line = br.readLine()) != null) {
  // Careful: line does not contain end of line characters
  bw.write(line + END_OF_LINE);
}
```

The readLine() method reads a line from the file. The line does not contain the end of line character(s). You have to add the end of line character(s) yourself if you want to write a new line.

Compile and execute the TextEndOfLineCharactersExample.java file. This will read the content of the file TextEndOfLineCharactersExample.java and write the file content to the file TextEndOfLineCharactersExample.txt with the end of line character(s).

While the System.lineSeparator() method returns the end of line character(s) for the current operating system, it is better to set a constant for the end of line character(s) in your program. This way, you can control the end of line character(s) and make sure that the file is written correctly for all systems.

Dealing with errors

When using the Java IO API, you need to open and close a file before and after reading or writing data.

If you do not close the file properly, you might lose data or corrupt the file.

When accessing a file, many things can go wrong. The file might not exist, the file might be corrupted, the file might be locked by another process, etc.

When you open a file, you need to handle these errors **not matter if you are work with binary or text data**. This is done with a try-catch-finally block or, more recently, with a try-with-resources block.

The common exceptions you might encounter are:

- FileNotFoundException: the file does not exist
- UnsupportedEncodingException: the file is encoded in an unsupported character encoding
- IOException: the file cannot be accessed for other reasons

The FileNotFoundException and UnsupportedEncodingException exceptions are inherited from the IOException exception.

The same applies when you will use the network in future chapters: the network might be down, the connection might be lost, etc.

You will have to manage these errors when you will work with the network.

Open the DealingWithErrorsExample.java file in the 05-java-ios directory to see how to handle errors when reading and writing data.

The following function is a bad example of how to handle errors when reading and writing binary data:

```java
public static void tryCatchWithoutFinallyExample() {
  try {
    Reader reader = new FileReader("missing.file");
    Writer writer = new FileWriter("missing.file");

    writer.write(reader.read());
  } catch (IOException e) {
    System.out.println("Exception: " + e);
  }
}
```

It catches an exception but does not close the resources properly as seen in the previous sections.

Even if the reader and writer would be closed after the `writer.write(reader.read());` line, it would be enough: if an error occurs when trying to write to the file (for reasons such as bad permissions, another process locking the file, etc.), the resources would not be closed properly.

This can lead to resource leaks (= resources that are not closed properly and that are not available for other parts of the program) and corrupted files.

A better way to handle errors is to use the `try-catch-finally` block as seen in the following function:

```
public static void tryCatchFinallyExample() {
  Reader reader = null;
  Writer writer = null;

  try {
    reader = new FileReader("missing.file");
    writer = new FileWriter("missing.file");

    writer.write(reader.read());
  } catch (IOException e) {
    System.out.println("Exception: " + e);
  } finally {
    if (writer != null) {
      try {
        writer.close();
      } catch (IOException e) {
        System.out.println("Exception in close writer: " + e);
      }
    }
```

```
      if (reader != null) {
        try {
          reader.close();
        } catch (IOException e) {
          System.out.println("Exception in close reader: " + e);
        }
      }
    }
  }
```

Using the finally block, the resources are closed properly whenever an error occurs or not. A finally block is always executed, even if no exception is thrown.

This solution is better than the previous one, but it is verbose and hard to read. Let's see how to handle errors with the try-with-resources block.

The try-with-resources block is a more concise and less error-prone way to handle errors when reading and writing data as seen in the following function:

```
public static void tryWithResourcesExample() {
  try (Reader reader = new FileReader("missing.file");
      Writer writer = new FileWriter("missing.file")) {
    writer.write(reader.read());
  } catch (IOException e) {
    System.out.println("Exception: " + e);
  }
}
```

The try-with-resources block is a try block that declares one or more resources. A resource is an object that must be closed after the program is done with it. The try-with-resources block ensures that each resource is closed at the end of the block.

While both try-catching-finally and try-with-resources blocks are valid ways to handle errors when reading and writing data, the try-with-resources block is the preferred way as it is more concise and less error-prone (you do not have to remember to close the resources in the finally block).

In order for a class to be used in a `try-with-resources` block, it must implement the `AutoCloseable` interface. All the classes presented in this chapter implement the `AutoCloseable` interface, whatever you are dealing with binary or text data.

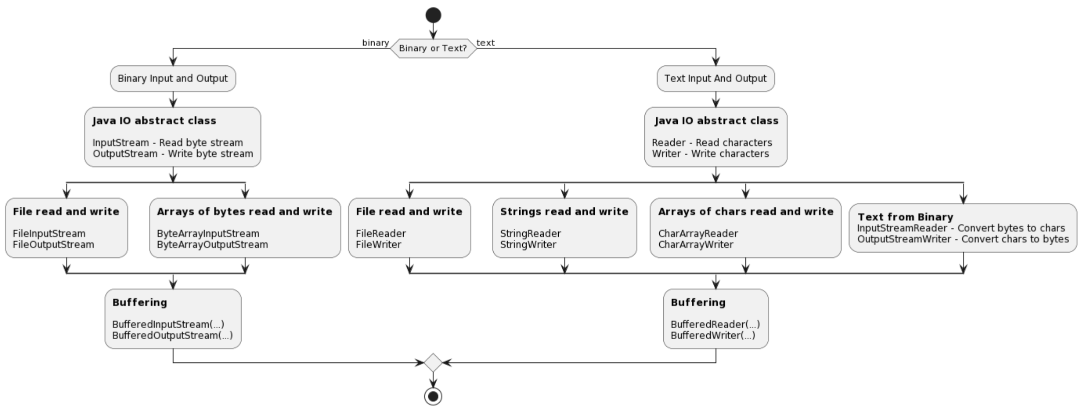
We highly recommend you to use the `try-with-resources` block as it is the preferred way to handle errors and close resources.

When to use which IO?

The Java IO API is very powerful. It can be used to read and write data from and to different sources and sinks of data using different types of streams.

It can sometimes be overwhelming to know which IO to use for which use case.

Here is a simple decision tree to help you choose the right IO for the right use case:



Common pitfalls

Always set the character encoding when you read or write text data. If you do not set the character encoding, the default character encoding will be used, which is not what you want as it can differ from other systems.

Always close the file after you have read or written data. If you do not close the file, you might lose data or corrupt the file as other processes might not

Always handle errors when you read or write data. If you do not handle errors, your program might crash and leave the files in an inconsistent state.

While reading the Java IO API, you might encounter the class `PrintWriter`. The `PrintWriter` class is a subclass of the `Writer` class that is used to write text data. It provides many conveniences where you do not have to handle the `flush()` and `close()` methods yourself. However, it does not handle errors properly as it does not throw exceptions when an error occurs. We will ask you not to use the `PrintWriter` class in this course. It is better to use the `BufferedWriter` class to write text data and handle errors properly.

You might also encounter the `System.lineSeparator()` method. The `System.lineSeparator()` method returns the end of line character(s) for the current operating system. As it is a system-dependent property, it is better to set a constant for the end of line character(s) in your program.

Practical content

In this practical content, you will use all the knowledge you have learned in this chapter to benchmark the different types of streams.

You will learn how to read and write data from and to different sources and sinks of data using different types of streams and benchmark the different types of streams to see which one is the most efficient for different use cases.

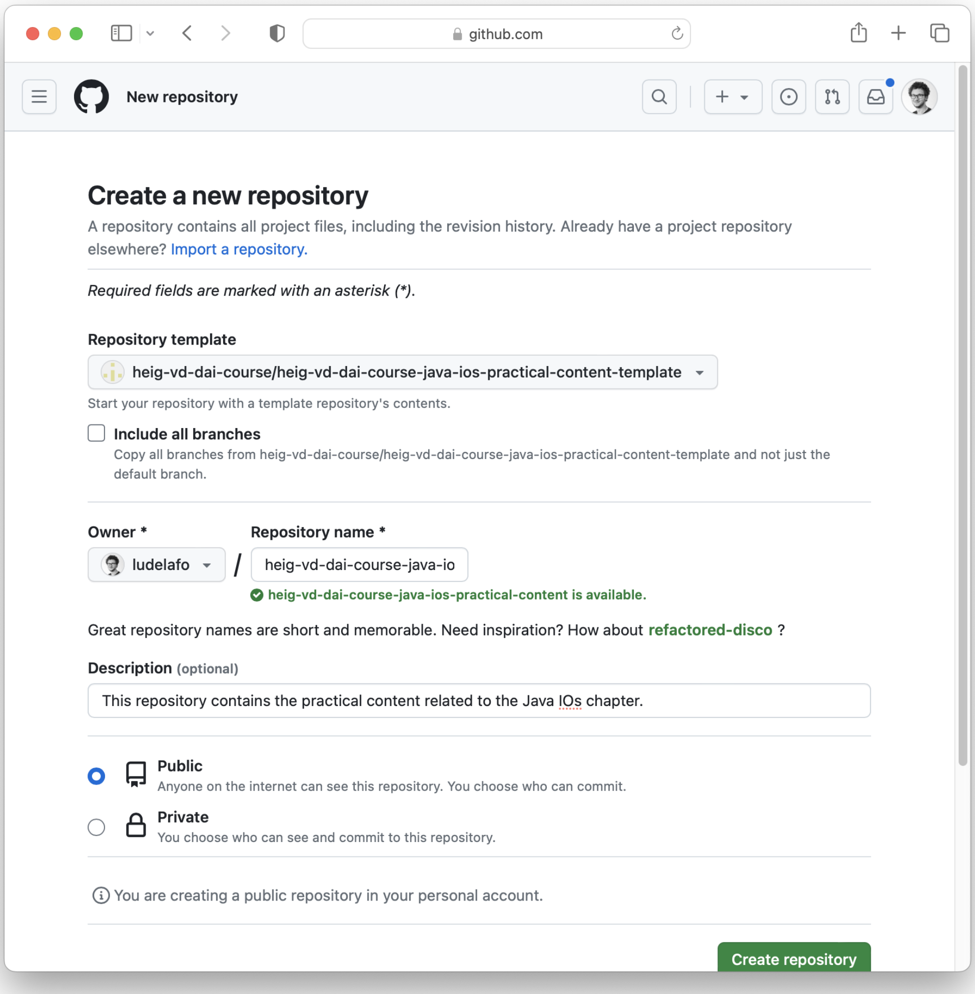
Create and clone the repository

You can create a new GitHub project using the template we have prepared for you.

When you create a new repository, you can choose to use a template. Select the `heig-vd-dai-course/heig-vd-dai-course-java-ios-practical-content` template as shown in the following screenshot:

Warning

Please make sure that the repository owner is your personal GitHub account and not the `heig-vd-dai-course` organization.


github.com

New repository

Create a new repository

A repository contains all project files, including the revision history. Already have a project repository elsewhere? Import a repository.

Required fields are marked with an asterisk (*).

Repository template

heig-vd-dai-course/heig-vd-dai-course-java-ios-practical-content-template

Start your repository with a template repository's contents.

☐ **Include all branches**
Copy all branches from heig-vd-dai-course/heig-vd-dai-course-java-ios-practical-content-template and not just the default branch.

Owner * ludelafo / **Repository name *** heig-vd-dai-course-java-io

✓ heig-vd-dai-course-java-ios-practical-content is available.

Great repository names are short and memorable. Need inspiration? How about refactored-disco ?

Description (optional)

This repository contains the practical content related to the Java IOs chapter.

● **Public**
Anyone on the internet can see this repository. You choose who can commit.

○ **Private**
You choose who can see and commit to this repository.

You are creating a public repository in your personal account.

Create repository

Clone the repository locally.

Implement the different types of streams

Take some time to explore the codebase from the template we have prepared for you.

You will benchmark the different types of streams to see which one is the most efficient for your use case:

- Open a binary file for byte per byte reading
- Write a binary file for byte per byte writing
- Open a binary file for buffer reading
- Write a binary file for buffer writing
- Open a text file for byte per byte reading
- Write a text file for byte per byte writing
- Open a text file for buffer reading

- Write a text file for buffer writing

You will then execute your CLI tool to write data of a certain size and read them back to compare the execution time.

Read the course material carefully to find the right classes to use. You can also have a look at the Java documentation to find more details on the right classes to use and how to use them: https://docs.oracle.com/en/java/javase/21/docs/api/.

Compare the results

Generate different files with different sizes (1B, 1KiB, 1MiB, 5MiB). Compare the results with the execution time of the different types of streams. Which one is the most efficient for each use case?

Share your results

Share your results in the GitHub Discussions of this organization: https://github.com/orgs/heig-vd-dai-course/discussions.

Create a new discussion with the following information:

- **Title**: DAI 2024-2025 - Java IOs benchmarking - First name Last Name
- **Category**: Show and tell
- **Description**: The link to your GitHub repository, the results of your benchmarking in Markdown table and add your conclusions to the following questions:
  - Which type of stream is the most efficient for each use case?
  - Why is it more efficient than the other types of streams?
  - What is the difference between binary data and text data?
  - What is a character encoding?
  - Why is this benchmark methodology important?

This will notify us that you have completed the exercise and we can check your work.

You can compare your solution with the official one stated in the Solution section, however, **we highly recommend you to try to complete the practical content by yourself first to learn the most**.

Go further

This is an optional section. Feel free to skip it if you do not have time.

- You can do the same benchmarking with the Java NIO API. How is it different from the Java IO API?

Conclusion

What did you do and learn?

In this chapter, you have learned how to read and write data from and to different sources and sinks of data using different types of streams, more specifically binary and text data.

You have learned the importance of character encodings and how to handle them when reading and writing data.

You have learned how to benchmark the different types of streams to find the most efficient one for your use case.

You have also learned how to handle errors to avoid your program to crash and leave the files in an inconsistent state.

Test your knowledge

At this point, you should be able to answer the following questions:

- What is a source of data?
- What is a sink of data?
- What is a stream?
- What is the difference between binary data and text data?
- What is a character encoding?
- What is UTF-8? How is it different from ASCII and Unicode?
- What happens if you ignore the character encoding?
- How is a buffer more efficient than reading or writing byte by byte?

Finished? Was it easy? Was it hard?

Can you let us know what was easy and what was difficult for you during this chapter?

This will help us to improve the course and adapt the content to your needs. If we notice some difficulties, we will come back to you to help you.

➡ GitHub Discussions

You can use reactions to express your opinion on a comment!

What will you do next?

In the next chapter, you will learn the following topics:

- Docker and Docker Compose: how to containerize your applications
  - What is an image?
  - What is a container?
  - How to try out new software without installing it?

Additional resources

Resources are here to help you. They are not mandatory to read.

- Informatique au gymnase : apprendre - Les caractères

Missing item in the list? Feel free to open a pull request to add it!

Solution

You can find the solution to the practical content in the heig-vd-dai-course/heig-vd-dai-course-solutions repository.

If you have any questions about the solution, feel free to open an issue to discuss it!

Sources

- Main illustration by Martijn Baudoin on Unsplash