



OOP with Java

28. I/O and Streams

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website

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- Streams are the preferred form of I/O in many scenarios

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- What the methods actually do depends on the implementations in the corresponding subclasses

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Listing: Copying a file byte-by-byte

```
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.IOException;

/** a class copying a raw file byte for byte: slow */
public class CopyRawFileBytewise {
    /** The main routine
     * @param args args[0]=source file, args[1]=target file */
    public static void main(String[] args) { // we use try-with-resource...
        try (final FileInputStream source = new FileInputStream(args[0])) {
            try (final FileOutputStream target = new FileOutputStream(args[1])) {
                int readByte;
                while ((readByte = source.read()) >= 0) { // while not end-of-stream
                    target.write(readByte); // write the byte we just read
                }
            } // closes target, the "}" in the next line closes source
        } catch (IOException error) { // IOExceptions are checked exceptions
            System.out.println("Copying has failed."); // $NON-NLS-1$
            error.printStackTrace(); // print stack trace
        }
    }
}
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- Copying files byte-by-byte this way means to do a lot of system calls and is slow
- We could instead allocate a buffer to hold several bytes at once and use the array-based methods

Listing: Copying a file using a buffer

```
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.IOException;

/** a class copying a raw file by using a buffer: faster */
public class CopyRawFileUsingBuffer {

    /** The main routine
     * @param args  args[0]=source file, args[1]=target file */
    public static void main(String[] args) { // we use try-with-resource...
        try (final FileInputStream source = new FileInputStream(args[0])) {
            try (final FileOutputStream target = new FileOutputStream(args[1])) {
                byte[] buffer = new byte[4096]; // a reasonable sized buffer
                int readAmount; // the number of bytes actually read

                while ((readAmount = source.read(buffer)) > 0) { // fill buffer
                    target.write(buffer, 0, readAmount); // write the bytes we just read
                }
            } // closes target, the "}" in the next line closes source
        } catch (IOException error) { // IOExceptions are checked exceptions
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- Based on the previous examples, we can now copy data from `stdin` to a file or from a file to `stdout` or `stderr`

Listing: Copying stdin to a file

```
import java.io.FileOutputStream;
import java.io.IOException;

/** a class copying all bytes read from stdin to a file by using a buffer:
    faster */
public class CopyStdInToFileUsingBuffer {

    /** The main routine
     * @param args  args[0]=target file */
    public static void main(String[] args) { // we use try-with-resource...
        try (final FileOutputStream target = new FileOutputStream(args[0])) {
            byte[] buffer = new byte[4096]; // a reasonable sized buffer
            int readAmount;                // the number of bytes actually read

            while ((readAmount = System.in.read(buffer)) > 0) { // fill buffer
                target.write(buffer, 0, readAmount); // write the bytes we just read
            }
        } catch (IOException error) { // IOExceptions are checked exceptions
            System.out.println("Copying has failed."); //$NON-NLS-1$
            error.printStackTrace(); // print stack trace
        }
    }
}
```

Listing: Copying a file to stdout

```
import java.io.FileInputStream;
import java.io.IOException;

/** a class copying a raw file to stdout by using a buffer: faster */
public class CopyFileToStdOutUsingBuffer {

    /** The main routine
     * @param args args[0]=source file */
    public static void main(String[] args) { // we use try-with-resource...
        try (final FileInputStream source = new FileInputStream(args[0])) {
            byte[] buffer = new byte[4096]; // a reasonable sized buffer
            int readAmount; // the number of bytes actually read

            while ((readAmount = source.read(buffer)) > 0) { // fill buffer
                System.out.write(buffer, 0, readAmount); // write the bytes we just read
            }
        } catch (IOException error) { // IOExceptions are checked exceptions
            System.out.println("Copying has failed."); // $NON-NLS-1$
            error.printStackTrace(); // print stack trace
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```


Listing: Copying a file to stderr

```
import java.io.FileInputStream;
import java.io.IOException;

/** a class copying a raw file to stdout by using a buffer: faster */
public class CopyFileToStdErrUsingBuffer {

    /** The main routine
     * @param args args[0]=source file */
    public static void main(String[] args) { // we use try-with-resource...
        try (final FileInputStream source = new FileInputStream(args[0])) {
            byte[] buffer = new byte[4096]; // a reasonable sized buffer
            int readAmount; // the number of bytes actually read

            while ((readAmount = source.read(buffer)) > 0) { // fill buffer
                System.err.write(buffer, 0, readAmount); // write the bytes we just read
            }
        } catch (IOException error) { // IOExceptions are checked exceptions
            System.out.println("Copying has failed."); // $NON-NLS-1$
            error.printStackTrace(); // print stack trace
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- `stdin (System.in)` is a `java.io.InputStream`
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- Based on the previous examples, we can now copy data from `stdin` to a file or from a file to `stdout` or `stderr`
- **Warning:** This is just an example, *never* use byte streams with text data...

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 - `ByteArrayInputStream(byte[] b, int off, int len)` reads only in the `len` bytes starting at offset `off`

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 - `DataOutputStream` is a subclass of `OutputStream` :
 - its constructor takes an `OutputStream` as parameter to which it will write
 - it additionally offers a method of the form `writeXXX` for writing one instance of each primitive type

Listing: Using Byte Array Streams and Data Streams

```
import java.io.ByteArrayInputStream;
import java.io.ByteArrayOutputStream;
import java.io.DataInputStream;
import java.io.DataOutputStream;
import java.io.IOException;

/** a class writing some primitive types to a buffer, printing the buffer, then reading the values again */
public class DataAndByteIOStreams {

    /** The main routine
     * @param args args[0]=target file */
    public static void main(String[] args) { // we use try-with-resource...
        byte[] buffer;

        try { // wrap all code in a huge try-catch clause
            try (ByteArrayOutputStream bos = new ByteArrayOutputStream()) {
                try (DataOutputStream dos = new DataOutputStream(bos)) {
                    dos.writeLong(0x88_99_aa_bb_cc_dd_ee_ffL); // write 64bit long to dos, results in 8 bytes to bos
                    dos.writeBoolean(true); // write true to dos, results in byte value 1 to bos
                    dos.writeFloat(2f); // write float 2f to dos, results in 4 bytes (0x40_00_00_00) to bos
                    dos.writeInt(8192 | 32); // 8192 | 32 = 0x0002020 to dos, resulting in 4 to bos
                } // automatically close the data output stream
                buffer = bos.toByteArray(); // get a copy of the buffer holding all writtendata
            } // close the byte array output stream

            System.out.print(buffer.length); // how many bytes were written? 8+1+4+4 = 17
            System.out.print('\n');
            for (byte b : buffer) { // fast read-only iteration over buffer
                System.out.print('u');
                System.out.print(Integer.toHexString(b & 0xff)); // write hex value of current byte
            } // -----long-----float----int-----
            System.out.println(); // 17: 88 99 aa bb cc dd ee ff 1 40 0 0 0 0 20 20
            // boolean--

            try (ByteArrayInputStream bis = new ByteArrayInputStream(buffer)) { // now we read again from the buffer
                try (DataInputStream dis = new DataInputStream(bis)) { // and wrap bis into data input stream
                    System.out.println(Long.toHexString(dis.readLong())); // read the long
                    System.out.println(dis.readBoolean()); // read the boolean
                    System.out.println(dis.readFloat()); // read the float
                    System.out.println(dis.readInt()); // read the int
                } // automatically close dis
            } // automatically close bis

        } catch (IOException error) { // if something failed (that should really not happen here) ...
            error.printStackTrace(); // ... print the stack trace
        }
    }
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 - `java.net.Socket`, implementing TCP sockets in Java, provides `java.io.InputStream` / `java.io.OutputStream` to read/write from an internet connection
 - `java.io.ObjectInputStream` / `java.io.ObjectOutputStream` are similar to the data input/output streams, but additionally allow for reading/writing whole (serializable) objects

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- **When dealing with text data, we *must* make sure to use the right encoding!**

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- `FileWriter` writes one character after the other to a file
 - It offers several constructors, one accepts the path to the file to be created and written to as `String`
 - It will transform the characters to raw binary data using the system's default character encoding

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- A first implementation of the file copying procedure could look like this:

Listing: Copying a text file character-by-character

```
import java.io.FileReader;
import java.io.FileWriter;
import java.io.IOException;

/** a class copying a text file character by character: slow */
public class CopyTextFileCharacterwise {

    /** The main routine
     * @param args  args[0]=source file, args[1]=target file */
    public static void main(String[] args) { // we use try-with-resource...
        try (final FileReader source = new FileReader(args[0])) {
            try (final FileWriter target = new FileWriter(args[1])) {
                int readCharacter;
                while ((readCharacter = source.read()) >= 0) { // while not end-of-stream
                    target.write(readCharacter);           // write the character we just read
                }
            } // closes target, the "}" in the next line closes source
        } catch (IOException error) { // IOExceptions are checked exceptions
            System.out.println("Copying has failed."); // $NON-NLS-1$
            error.printStackTrace(); // print stack trace
        }
    }
}
```

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- Copying files character-by-character this way means to do a lot of system calls and is slow
- We could instead allocate a buffer to hold several characters at once and use the array-based methods

Listing: Copying a text file using a buffer

```
import java.io.FileReader;
import java.io.FileWriter;
import java.io.IOException;

/** a class copying a text file by using a buffer: faster */
public class CopyTextFileUsingBuffer {

    /** The main routine
     * @param args  args[0]=source file, args[1]=target file */
    public static void main(String[] args) { // we use try-with-resource...
        try (final FileReader source = new FileReader(args[0])) {
            try (final FileWriter target = new FileWriter(args[1])) {
                char[] buffer = new char[4096]; // a reasonable sized buffer
                int readAmount; // the number of characters actually read

                while ((readAmount = source.read(buffer)) > 0) { // fill buffer
                    target.write(buffer, 0, readAmount); // write the characters we just read
                }
            } // closes target, the "}" in the next line closes source
        } catch (IOException error) { // IOExceptions are checked exceptions
            System.out.println("Copying has failed."); // $NON-NLS-1$
            error.printStackTrace(); // print stack trace
        }
    }
}
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 - writes its data to an `java.io.OutputStream` passed to it in its constructor
 - as optional second parameter, the name of a text encoding can be provided (otherwise, the system's default encoding is used)
- These character streams thus can be used in any situation where we have byte streams, e.g., to work on `stdin/stdout` or on socket-provided streams of a TCP/IP internet connection

- The code below is fully equivalent to the previous example. . .

Listing: Text File Copying using Character Streams wrapped around Byte Streams

```
import java.io.FileInputStream;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.InputStreamReader;
import java.io.OutputStreamWriter;

/** a class copying a text file by using character streams wrapped around byte streams */
public class CopyTextFileUsingBufferAndWrappedStreams {

    /** The main routine
     * @param args args[0]=source file, args[1]=target file */
    public static void main(String[] args) { // we use try-with-resource...

        try (final FileInputStream fis = new FileInputStream(args[0])) {
            try (final InputStreamReader source = new InputStreamReader(fis)) {

                try (final FileOutputStream fos = new FileOutputStream(args[1])) {
                    try (final OutputStreamWriter target = new OutputStreamWriter(fos)) {

                        char[] buffer = new char[4096]; // a reasonable sized buffer
                        int readAmount; // the number of characters actually read

                        while ((readAmount = source.read(buffer)) > 0) { // fill buffer
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 - `java.io.BufferedReader` is wrapped around a `java.io.Reader` and offers not just faster, buffered reading, but also the ability to read a complete *line* of text via the method `String readLine()` returning a `String` containing a full line of text from its source (or `null` if the end of stream has been reached)

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 - `java.io.BufferedWriter` is wrapped around a `java.io.Writer` offers buffered writing and the method `newLine()` which starts a new line in the text output
 - `java.io.CharArrayReader` and `java.io.CharArrayWriter` are the character stream equivalent of the byte stream `java.io.ByteArrayInputStream` and `java.io.ByteArrayOutputStream`

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- Algorithms working on streams are thus naturally versatile
- Java further makes heavy use of the concept of plugging streams together, e.g., we would normally have an `java.io.InputStream`, wrap it into a `java.io.Reader`, which we would then wrap into a `java.io.BufferedReader` to be able to read text line-by-line

谢谢

Thank you

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Caspar David Friedrich, "Der Wanderer über dem Nebelmeer", 1818
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