Input/Output

Object Oriented Programming

http://softeng.polito.it/courses/09CBI

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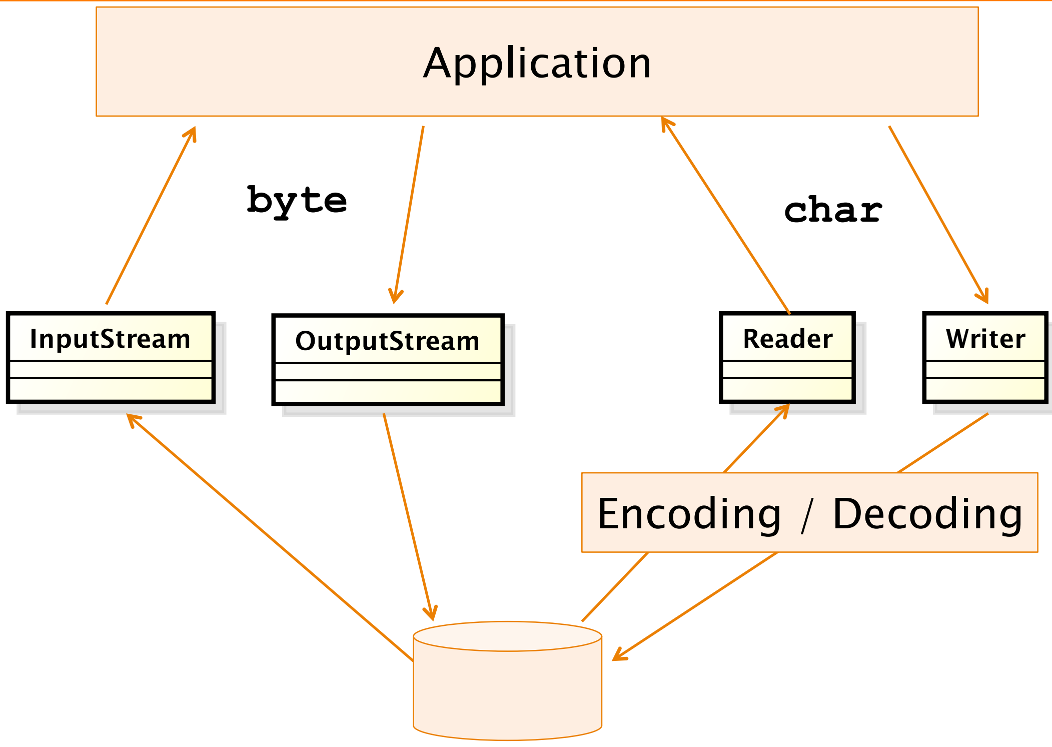
Stream

- All I/O operations rely on the abstraction of stream (flow of elements)
- A stream can be linked to:
  - A file on the disk
  - Standard input, output, error
  - A network connection
  - A data-flow from/to whichever hardware device
- I/O operations work in the same way with all kinds of stream

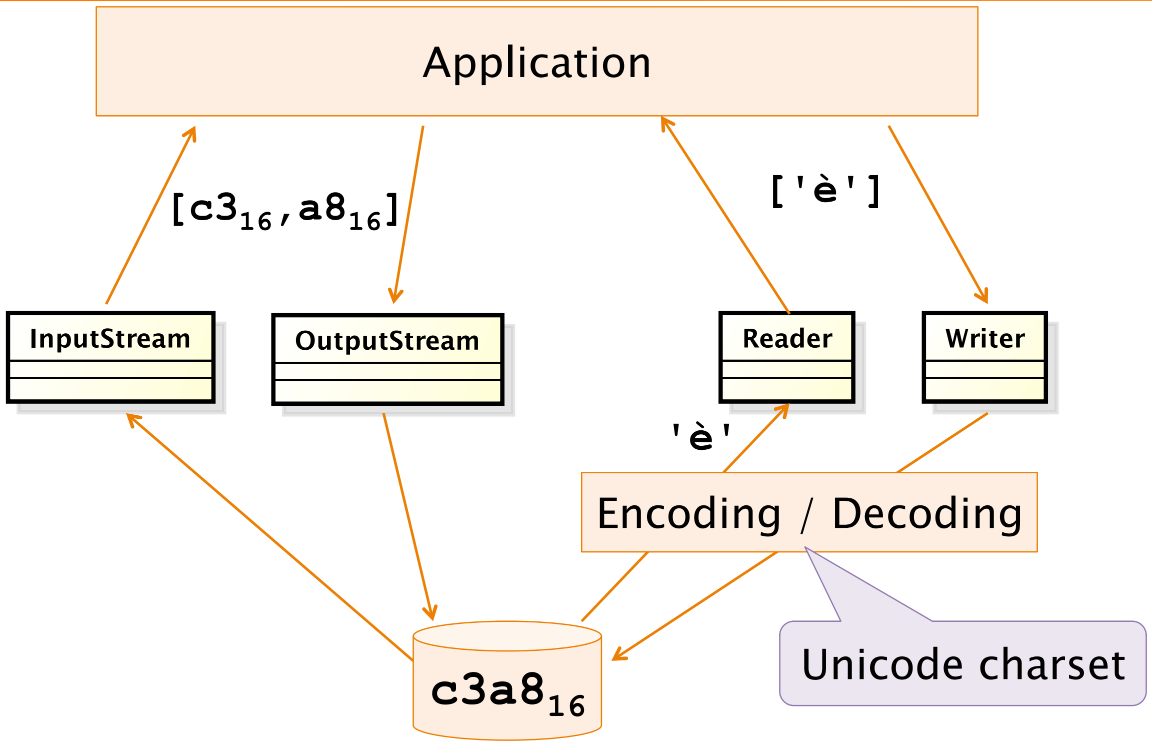
Stream

- Package: **`java.io`**
- **`Reader`** / **`Writer`**
  - stream of chars (Unicode chars - 16 bit)
    - All characters
- **`InputStream`** / **`OutputStream`**
  - stream of bytes (8 bit)
    - Binary data, sounds, images
- All related exceptions are subclasses of **`IOException`**

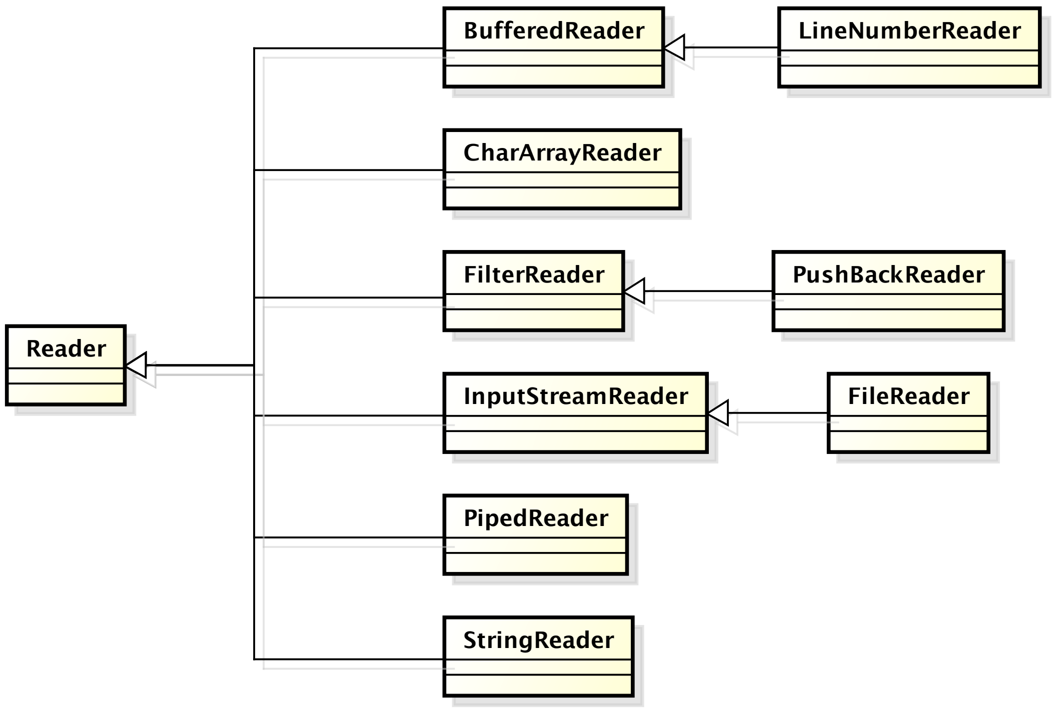
Byte vs. Char Oriented Streams



Byte vs. Char Example



Readers



`Reader` (abstract)

`void close()`
- Close the stream.

`int read()`
- Read a single character:
- Returns -1 when end of stream

`int read(char[] cbuf)`
- Read characters into an array.

`int read(char[] cbuf, int off, int len)`
- Read characters into a portion of an array.

Blocking methods i.e. stop until
- data available,
- I/O error, or
- end of stream

`Reader` (abstract)

- `boolean ready()`
  - Tell whether the stream is ready to be read.
- `void reset()`
  - Reset the stream, restart from beginning
- `long skip(long n)`
  - Skip n characters

Read a char

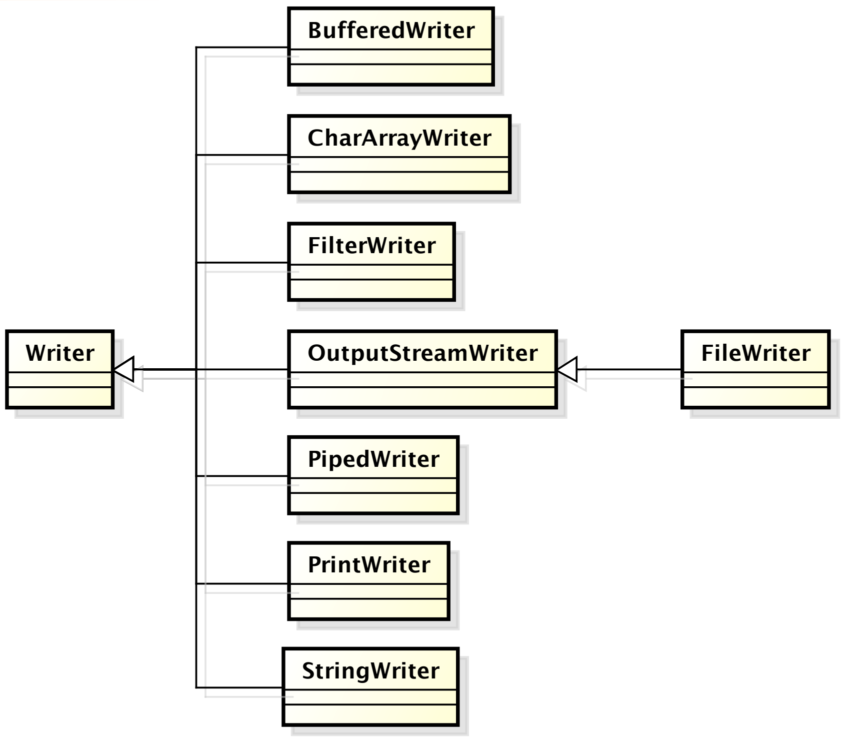
```
int ch = r.read();
char unicode = (char) ch;
System.out.print(unicode);
r.close();
```

Character	ch	unicode
‘A’	0…00000000 01000001$_{bin}$ = 65$_{dec}$	65
‘\n’	0…00000000 00001101$_{bin}$ = 13$_{dec}$	13
End of file	1…11111111 11111111$_{bin}$ = −1$_{dec}$	–

Read a line

```
public static String readLine(Reader r)
throws IOException{
  StringBuffer res= new StringBuffer();
  int ch = r.read();
  if(ch == -1) return null; // END OF FILE!
  while( ch != -1 ){
    char unicode = (char) ch;
    if(unicode == '\n') break;
    if(unicode != '\r') res.append(unicode);
    ch = r.read();
  }
  return res.toString();
}
```

Writers



`Writer` (abstract)

`void write(int c)`
- Write a single character.

`void write(char[] cbuf)`
- Write an array of characters.

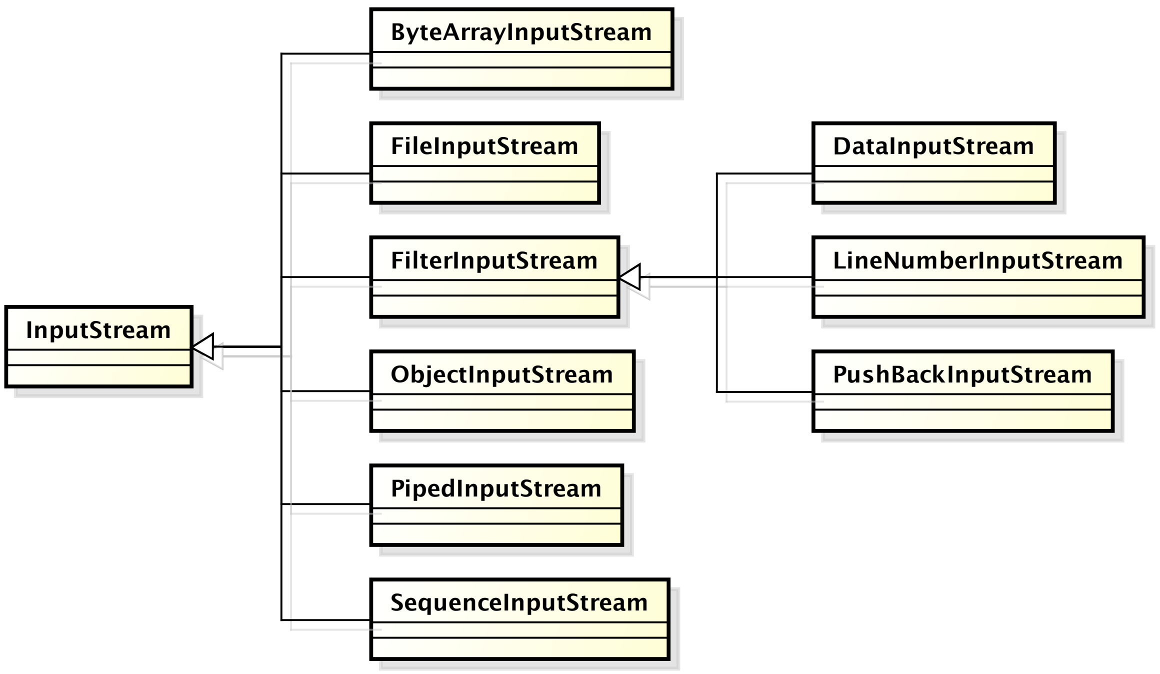
`void write(char[] cbuf, int off, int len)`
- Write a portion of an array of characters.

`void write(String str)`
- Write a string.

`close()`
- Close the stream, flushing it first.

`abstract void flush()`
- Flush the stream.

Input streams



InputStream

`void close()`

- Closes this input stream and releases any system resources associated with the stream.

`int read()`

- Reads the next byte of data from the input stream.

`int read(byte[] b)`

- Reads some number of bytes from the input stream and stores them into the buffer array b.

`int read(byte[] b, int off, int len)`

- Reads up to len bytes of data from the input stream into an array of bytes.

InputStream

`int available()`

- Returns the number of bytes that can be read (or skipped over) from this input stream without blocking by the next caller of a method for this input stream.

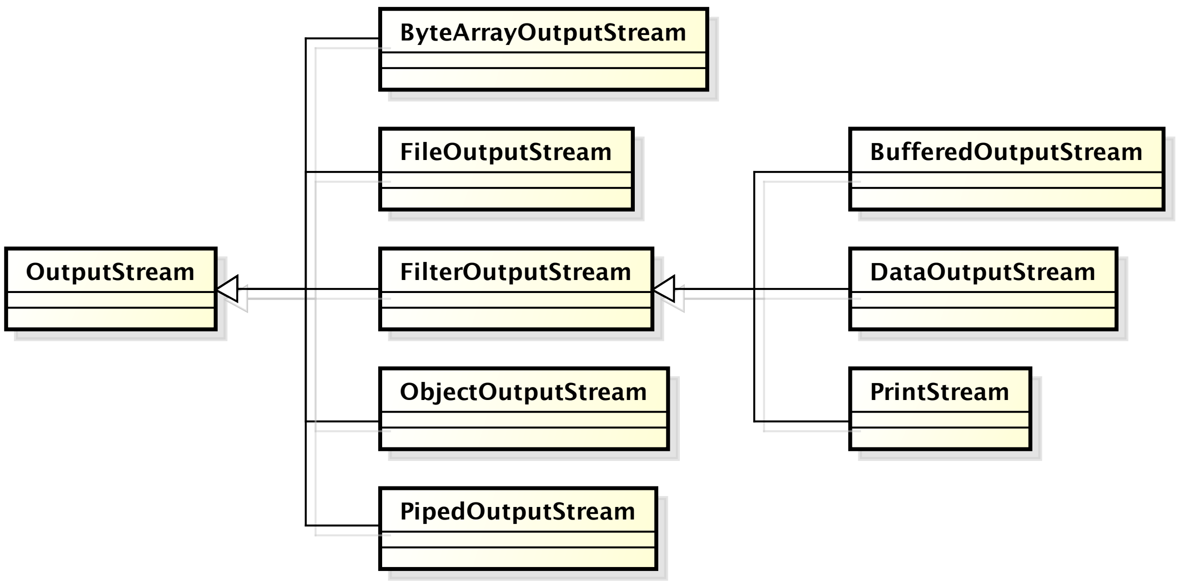
`void reset()`

- Repositions this stream to the position at the time the mark method was last called on this input stream.

`long skip(long n)`

- Skips over and discards n bytes of data from this input stream.

Output streams



OutputStream

void write(byte[] b)
- Writes b.length bytes from the specified byte array to this output stream.

void write(byte[] b, int off, int len)
- Writes len bytes from the specified byte array starting at offset off to this output stream.

void write(int b)
- Writes the specified byte to this output stream.

void close()
- Closes this output stream and releases any system resources associated with this stream.

void flush()
- Flushes this output stream and forces any buffered output bytes to be written out.

Stream specializations

- Memory
- Pipe
- File
- Buffered
- Printed
- Interpreted

Conversion byte <-> char

- **`InputStreamReader`**
  char ← byte
- **`OutputStreamWriter`**
  char → byte
- The constructors allow specifying a charset to decode/encode the byte to/from characters

Read/Write in memory

- `CharArrayReader`
- `CharArrayWriter`
- `StringReader`
- `StringWriter`
  - R/W chars from/to array or String
- `ByteArrayInputStream`
- `ByteArrayOutputStream`
  - R/W bytes from/to array in memory

R/W of Pipe

- Pipes are used for inter-thread communication they must be used in connected pairs
- `PipedReader`
- `PipedWriter`
  - R/W chars from pipe
- `PipedInputStream`
- `PipedOutputStream`
  - R/W bytes from pipe

R/W of File

- Used for reading/writing files
- `FileReader`
- `FileWriter`
  - R/W chars from file
- `FileInputStream`
- `FileOutputStream`
  - R/W bytes from file

Copy text file

```
Reader src = new FileReader(args[0]);
Writer dest = new FileWriter(args[1]);
int in;
while( (in=src.read()) != -1){
  dest.write(in);
}
src.close();
dest.close();
```

One char at a time is higly inefficient!

Copy text file with buffer

```
Reader src = new FileReader(args[0]);
Writer dest = new FileWriter(args[1]);
char[] buffer = new char[4096];
int n;
while((n = src.read(buffer))!=-1){
  dest.write(buffer,0,n);
}
src.close();
dest.close();
```

The buffered version is 10 times faster

Buffered

- **BufferedInputStream**
  `BufferedInputStream(InputStream i)`
  `BufferedInputStream(InputStream i, int s)`
- **BufferedOutputStream**
- **BufferedReader**
  `readLine()`
- **BufferedWriter**

Printed streams

- **PrintStream**(OutputStream o)
  - Provides general printing methods for all primitive types, String, and Object
    - `print()`
    - `println()`
  - Designed to work with basic byte oriented console
  - Does not throw **`IOException`**, but it sets a bit, to be checked with method **`checkError()`**

Standard in & out

- Default input and output streams are defined in class System

```
class System {
  //…
  static InputStream in;
  static PrintStream out;
  static PrintStream err;
}
```

Replacing standard streams

- Default streams can be replaced
  - **setIn(), setOut(), setErr()**

```
String input = "This is\nthe input\n";
InputStream altInput = new
    ByteArrayInputStream(input.getBytes());
InputStream oldIn = System.in;
System.setIn(altInput);
readLines();
System.setIn(oldIn);
```

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Interpreted streams

- Translate primitive types into / from standard format
  - Typically on a file
- **DataInputStream**(InputStream i)
  - readByte(), readChar(), readDouble(), readFloat(), readInt(), readLong(), readShort(), ..
- **DataOutputStream**(OutputStream o)
  - like write()

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URLs

- Streams can be linked to URL

```
URL page = new URL(url);
InputStream in = page.openStream();
```

- ♦ Be careful about the type of file you are downloading.

Download file

```
URL home = new URL("http://…");
URLConnection con = home.openConnection();
String ctype = con.getContentType();
if(ctype.equals("text/html")){
  Reader r = new InputStreamReader(
                           con.getInputStream());
  Writer w = new OutputStreamWriter(System.out);
  char[] buffer = new char[4096];
  while(true){
    int n = r.read(buffer);
    if(n==-1) break;
    w.write(buffer,0,n);
  }
  r.close(); w.close();
}
```

Stream as resources

- Streams consume OS resources
  - Should be closed as soon as possible to release resources

```
String readFirstLine(String path)
                               throws IOException{
   BufferedReader br=new BufferedReader(
                          new FileReader(path));
   String l = br.readLine();
   br.close()
   return l
}
```

What happens in case of exception in **readLine** ?

Missing close with exception

```
String readFirstLine(String path)
                               throws IOException{
   BufferedReader br=new BufferedReader(
                          new FileReader(path));

   String l = br.readLine();
   br.close()
   return l
}
```

What happens in case of exception in **readLine** ?

Catch and close

```
String readFirstLine(String path)
                              throws IOException {
    BufferedReader br=new BufferedReader(
                            new FileReader(path));
    try {
        String l = br.readLine();
        br.close();
        return l
    } catch(IOException e){
         br.close();
         throw e;
    }
}
```

Complex and does not close in case of `Error`

Finally close

```
String readFirstLine(String path)
                              throws IOException {
    BufferedReader br=new BufferedReader(
                            new FileReader(path));
    try {
          return br.readLine();
    } finally {
          if(br!=null) br.close();
    }
}
```

Executed in any case before exiting the method

Try-with-resource

```
String readFirstLine(String path)
                              throws IOException {
    try(
    BufferedReader br=new BufferedReader(
                          new FileReader(path))){
        return br.readLine();
    }
}
```

Works since `BuffereReader` implements `Autocloseable`

```
public interface AutoCloseable{
  public void close();
}
```

SERIALIZATION

Serialization

- Read / write of an object imply:
  - read/write attributes (and optionally the type) of the object
  - Correctly separating different elements
  - When reading, create an object and set all attributes values
- These operations (serialization) are automated by
  - **`ObjectInputStream`**
  - **`ObjectOutputStream`**

Using Serialization

- Methods to read/write objects are:

```
void writeObject(Object)
Object readObject()
```

- ONLY objects implementing interface **`Serializable`** can be serialized
  - This interface is empty

  ⇒Just used to avoid serialization of objects, without permission of the class developer

Type recovery

- When reading, an object is created
- ... but which is its type?
- In practice, not always a precise downcast is required:
  - Only if specific methods need to be invoked
  - A downcast to a common ancestor can be used to avoid identifying the exact class

Saving Objects with references

- Serialization is applied recursively to object in references
- Referenced objects must implement the **`Serializable`** interface
- Specific fields can be excluded from serialization by marking them as **`transient`**

Saving Objects with references

- An **`ObjectOutputStream`** saves all objects referred by its attributes
  - objects serialized are numbered in the stream
  - references are saved as ordering numbers in the stream
- If two saved objects point to a common one, this is saved just once
  - Before saving an object, **`ObjectOutputStream`** checks if it has not been already saved
  - Otherwise it saves just the reference

Serialization

```
public class Student
implements Serializable {…}
```

```
List<Student> students=new LinkedList<>();
students.add( ... );
...
ObjectOutputStream serializer =
       new ObjectOutputStream(
           new FileOutputStream(”std.dat"));
serializer.writeObject(students);
serializer.close();
```

```
ObjectInputStream deserializer =
          new ObjectInputStream(
             new FileInputStream("std.dat"));
Object retrieved = deserializer.readObject();
deserializer.close();
List<Student> l = (List<Student>)retrieved;
```

FILE

File

- Abstract pathname
  - directory, file, file separator
  - absolute, relative
- convert abstract pathname <--> string
- Methods:
  - **`create() delete() exists() , mkdir()`**
  - **`getName() getAbsolutePath(), getPath(), getParent(), isFile(), isDirectory()`**
  - **`isHidden(), length()`**
  - **`listFiles(), renameTo()`**

Example: list files

- List the files contained in the current working folder

```
File cwd = new File(".");
for(File f : cwd.listFiles()){
  System.out.println(f.getName()+ " "
                              + f.length());
}
```

New IO (**nio**)

- Paths and Files
  - Abstract path manipulation
  - Static methods
- Buffer and Channels
  - Buffer oriented IO
  - Leverages efficient memory transfers (DMA)

Class **`Path`**

- Represents path in the file system
  - Components extraction:
    - E.g. **`getFileName()`**
  - Navigation:
    - E.g. **`getParent()`**, **`getRoot()`**
  - Relative paths
    - **`relativize()`**
    - **`isAbsolute()`**
    - **`resolve()`**

Class File

- Provides methods to operate on Paths
  - Copy content: **`copy()`**
  - Create: **`createFile()`**
  - Test properties: **`isWritable()`**
  - Navigate: **`list()`**, **`find()`**
  - Create stream: **`newInputStream()`**
  - Create channel: **`newByteChannel()`**
  - Read: **`lines()`**
  - Write: **`write()`**

Example

- Compute max line length

```
Path d = Paths.get("file.txt")
int maxLen = 0;
if(Files.exists(d)){
  maxLen = Files.lines(d).
           mapToInt(String::length).
           max().getAsInt();
}
```

Tokenizers

- **StringTokenizer**
  - Works on String
  - set of delimiters (blank, “,”, \t, \n, \r, \f)
  - Blank is the default delimiter
  - Divides a String in tokens (separated by delimiters), returning the token
  - **hasMoreTokens(), nextToken()**
  - Does not distinguish identifiers, numbers, comments, quoted strings

Tokenizers

- `StreamTokenizer`
  - Works on Stream (Reader)
  - More sophisticated, recognizes identifiers, comments, quoted string, numbers
  - use symbol table and flag
  - **`nextToken()`**, TT_EOF if at the end

Summary

- Java IO is based on the stream abstraction
- Two main stream families:
  - Char oriented: Reader/Writer
  - Byte oriented: Input/OutputStream
- There are streams specialized for
  - Memory, File, Pipe, Buffered, Print

Summary

- Streams resources need to be closed as soon as possible
  - Try-with-resource construct guarantee resource closure even in case of exception
- Serialization means saving/restoring objects using Object streams
  - **`Serializable`** interface enables it