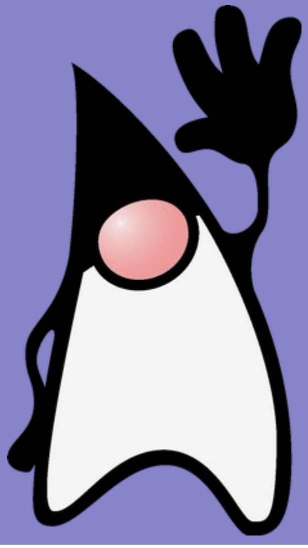
Java

Input/Output

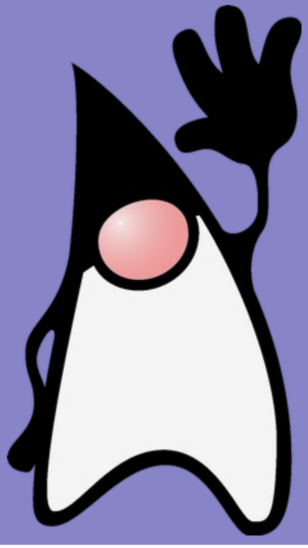


Overview

- package java.io
  - basic input/output
  - streams
    - bytes
  - Reader and Writer
    - chars (Unicode)
- package java.nio
  - channels, buffers
  - increased performance
    - classes from java.io internally implemented via java.nio
- java.io.Console
  - access to the character console (if exists)
- NIO.2 – since Java 7
  - mainly the package java.nio.file
  - operations with files, walking trees,...

Input/Ouput

Path



Path

- java.nio.file.Path
  - interface
  - represents a path
  - obtaining a path
    - Paths.get(String first, String... more)
      - static method
      - ex.
        Path p = Paths.get("home", "petr", "text.txt");
    - Path.of(String first, String... more)
      - since Java 11
      - the same as Paths.get()
      - recommended to use
        - Paths maybe deprecated in future

    - FileSystems.getDefault().getPath(String first, String... more)
      - Path.of() – uses a default filesystem

Path – methods

- path comparison
  - equals(), startsWith(), endsWith()
- relativization

```
Path p1 = Paths.get("joe");
Path p2 = Paths.get("sally");
Path p1_to_p2 = p1.relativize(p2);   // -> ../sally
```

- obtaining actual path of a symlink
  - toRealPath()
- Path implements Iterable<Path>
  - iterates over the path's components
- normalize()
  - removing redundant path elements
    - d1/././d2/ => d1/d2
- ...

Path – watching for changes

- WatchKey register(WatchService watcher, WatchEvent.Kind<?>... events)

```
WatchService watchService =
FileSystems.getDefault().newWatchService();
WatchKey key = this.path.register(watchService,
ENTRY_CREATE, ENTRY_DELETE);
while (true) {
  for (WatchEvent<?> l : key.pollEvents()) {
    ...
  }
  boolean valid = key.reset();
  if (!valid) {
    …
  }
}
```

java.nio.file.Files

- only static methods
  - copy(.. src, .. target, CopyOptions... options)
    - CopyOptions
      - REPLACE_EXISTING
      - COPY_ATTRIBUTES
      - NOFOLLOW_LINKS
  - move(.. src, .. target, CopyOptions... options)
    - CopyOptions
      - ATOMIC_MOVE
      - REPLACE_EXISTING
  - delete(), deleteIfExists()
  - byte[] readAllBytes(Path p)
  - List<String> readAllLines(Path path)
  - Path write(Path path, byte[] bytes, OpenOption... options)
  - Path write(Path path, Iterable<? extends CharSequence> lines, Charset cs, OpenOption... options)

CopyOptions, OpenOptions,...

- interfaces
- used in methods of the Files class

- implementations
  - StandardCopyOptions
    - enum (ATOMIC_MOVE, COPY_ATTRIBUTES,...)
  - StandardOpenOptions
    - enum (APPEND, READ, WRITE,...)
  - LinkOptions
    - enum (NOFOLLOW_LINKS)

java.nio.file.Files

- (cont.)
  - Path createLink(Path link, Path existing)
  - Path createSymbolicLink(Path link, Path target, FileAttribute<?>... attrs)
  - createDirectory(Path dir, FileAttribute<?>... attrs)
  - createDirectories(Path dir, FileAttribute<?>... attrs)
  - createFile(Path path, FileAttribute<?>... attrs)
  - createTempFile(String prefix, String suffix, FileAttribute<?>... attrs)
  - createTempFile(Path dir, String prefix, String suffix, FileAttribute<?>... attrs)

  - long mismatch(Path path, Path path2)
  - “test” methods
    - isDirectory()
    - isRegularFile()
    - is....()

java.nio.file.Files

- walking a file/direcotory tree
  - Path walkFileTree(Path start, FileVisitor<? super Path> visitor)
    - method of Files
  - interface FileVisitor<T>
    - FileVisitResult preVisitDirectory(T dir, BasicFileAttributes attrs)
    - FileVisitResult postVisitDirectory(T dir, IOException exc)
    - FileVisitResult visitFile(T file, BasicFileAttributes attrs)
    - FileVisitResult visitFileFailed(T file, IOException exc)

java.nio.file – ex. – deleting a complete tree

```
Path start = ...
Files.walkFileTree(start, new SimpleFileVisitor<Path>() {
  public FileVisitResult visitFile(Path f,
                               BasicFileAttributes attrs) throws IOException {
    Files.delete(file);
    return FileVisitResult.CONTINUE;
  }
  public FileVisitResult postVisitDirectory(Path dir,
                                           IOException e) throws IOException {
    if (e == null) {
      Files.delete(dir);
      return FileVisitResult.CONTINUE;
    } else {
      throw e;
    }
  }
});
```

java.io.File

- since Java 1.0
  - java.nio.files.Path – since Java 7
  - java.io.File is not deprecated
    - used in many places in the std. library

- also represents a path
  - similar usage as Path
  - but Path has better functionality
- conversions between them
  - File.toPath()
  - Path.toFile()

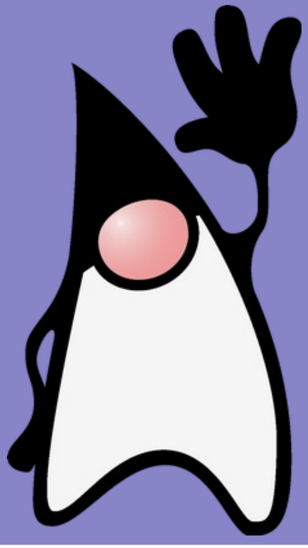
always prefer Path
(if possible)

Path / file separators

- fields of java.io.File
  - `static String pathSeparator`
  - `static char pathSeparatorChar`
    - path separator
  - `static String separator`
  - `static char separatorChar`
    - name separator in paths
- a method of java.nio.file.FileSystem
  - `String getSeparator()`

Input/Output

Streams



Overview

- InputStream
  - `int read()`
    - reads one byte from an input (returns -1 if the end is reached)
  - `int read(byte[] b)`
    - reads several bytes (returns number of read bytes or -1)
- OutputStream
  - `void write(int b)`
  - `void write(byte[] a)`
- all other I/O classes derived from the InputStream/OutputStream
  - children are used
  - InputStream and OutputStream are abstract

Input streams

- `ByteArrayInputStream`
  - reads from a buffer in memory
- `StringArrayInputStream`
  - converts a string to an input stream
- `FileInputStream`
  - reads form a file
- `PipedInputStream`
  - "reading" end of a pipe
  - for data passing between threads
- `SequenceInputStream`
  - concatenation of several streams

- all of them has only basic read() methods
  - reading by bytes

Output streams

- `ByteArrayOutputStream`
  - writes to a buffer in memory
- `FileOutputStream`
  - writes to a file
- `PipedOutputStream`
  - "writing" end of a pipe
  - for data passing between threads
- no `StringArrayOutputStream`
  - ByteArrayOutputStream can be used

- all of them has only basic write() methods
  - writing by bytes

Filters

- `FilterInputStream`
- `FilterOutputStream`
- abstract classes
  - many children
- via filters, further functionality is added to the basic streams
  - a filter receives another stream as a parameter of the constructor
  - data are read/written through the filter
- basic streams are almost always used via a stream
- several filters can be applied over a single stream

Types of filters

- `DataOutputStream`
  - defines the write method for all primitive types
- `DataInputStream`
  - defines the read method for all primitive types
  - reads data in the same format as written by DataOutputStream
    - the format is platform independent
- `BufferedInputStream`
- `BufferedOutputStream`
  - do not add new read/write methods
  - I/O will be buffered
    - basic streams are not
  - capacity of the buffer can be specified

Types of filters

- `LineNumberInputStream`
  - information about current line
- `PushbackInputStream`
  - can return data back to the stream

Types of filters

- `PrintStream`
  - writes data in a human readable form
    - DataOutputStream writes data to be read by DataInputStream
  - defines methods `print()` and `println()` for "all" types
  - method `printf()`
    - as printf in C
  - method `flush()`
    - writes the buffer to an underlaying stream
    - PrintStream is automatically buffered
    - `flush()` is called automatically when a new line is written
      - autoflush after each write can be set in a constructor
  - methods do not throw IOException
    - method `checkError()`

Usage

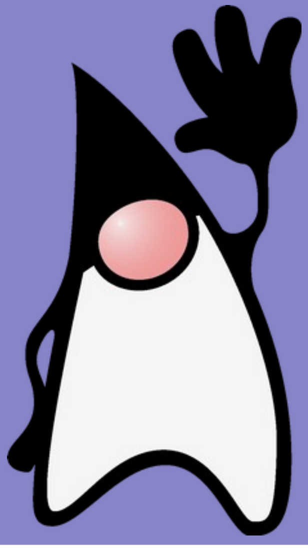
- layering filters over basic I/O streams

```
DataInputStream di = new DataInputStream(
         new BufferedInputStream (
           new FileInputStream("file.txt")));
int a = di.readInt();
long b = di.readLong();

DataOutputStream ds = new DataOutputStream(
         new BufferedOutputStream (
           new FileOutputStream("file.txt")));
ds.writeInt(100);
ds.writeLong(1234L);
```

on java.nio.file.Files there are “shortcut” methods for opening

Input/Output

Reader & Writer



Overview

- char-oriented I/O
  - char = 2 bytes
- streams are for binary data

- `Reader`
  - defines the read method for reading a char and array of chars
- `Writer`
  - defines the write method for writing a char and array of chars

- `Reader` and `Writer` – abstract classes
- `InputStreamReader`, `OutputStreamWriter`
  - creating Reader/Writer from a stream

Types of I/O

- similar to streams

InputStream	Reader InputStreamReader
OutputStream	Writer OutputStreamWriter
FileInputStream	FileReader
FileOutputStream	FileWriter
StringBufferInputStream	StringReader
-	StringWriter
ByteArrayInputStream	CharArrayReader
ByteArrayOutputStream	CharArrayWriter
PipedInputStream	PipedReader
PipedOutputStream	PipedWriter

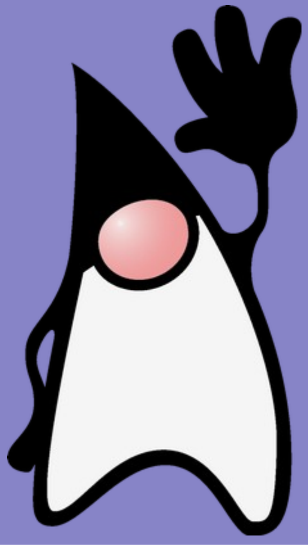
Filters

- again similar to streams

FilterInputStream	FilterReader
FilterOutputStream	FilterWriter
BufferedInputStream	BufferedReader
BufferedOutputStream	BufferedWriter
PrintStream	PrintWriter
LineNumberInputStream	LineNumberReader
PushbackInputStream	PushbackReader

Input/Output

Exception management



Exceptions

- almost “everything” in java.io throws IOException
  - extends Exception
  - needs to be caught/declared

File copy

```
InputStream is;
OutputStream os;
try {
  is = new FileInputStream(finNm);
  os = new FileOutputStream(foutNm);
  int c;
  while ((c = is.read()) != -1) {
    os.write(c);
  }
  os.close();
  is.close();
} catch (IOException ex) {
  System.out.println("Exception occured");
}
```

Is this code OK?

File copy

```
InputStream is;
OutputStream os;
try {
  is = new FileInputStream(finNm);
  os = new FileOutputStream(foutNm);
  int c;
  while ((c = is.read()) != -1) {
    os.write(c);
  }
  os.close();
  is.close();
} catch (IOException ex) {
  System.out.println("Exception occured");
}
```

NO

Is this code OK?

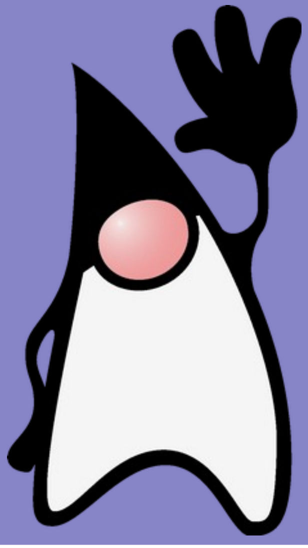
Exceptions

- streams and readers/writers implement AutoCloseable
- always use *try with resources*

```
try (InputStream is = new FileInputStream(finNm);
     OutputStream os = new FileOutputStream(foutNm)) {
  int c;
  while ((c = is.read()) != -1) {
    os.write(c);
  }
} catch (IOException ex) {
  System.out.println("Exception occured");
}
```

Input/Output

RandomAccessFile

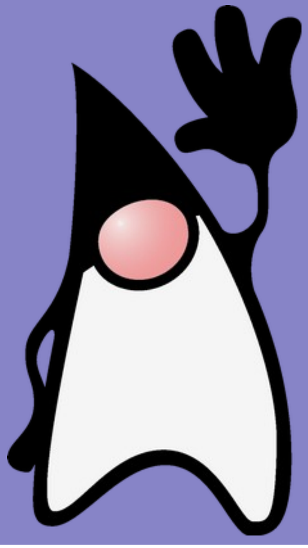


Overview

- reading and writing records from/to files
- movement over the file
- outside hierarchy of streams
- implements the interfaces DataInput and DataOutput
  - these interfaces are implemented by DataInputStream resp. DataOutputStream
  - methods read and write for primitive types
- opens the file for either reading only or reading and writing
  - the constructor parameter
    - "r" or "rw"

Input/Output

NIO



Overview

- “new I/O"
- since Java 1.4
- better performance
  - closer to structures of I/O in OS
- classes from java.io (stream and reader/writer) implemented java.nio classes
  - i.e., no need to use channels in “regular” programs
- defines *channels* and *buffers*
  - communication with a channel is by buffer only
- `FileInputStream`, `FileOutputStream` and `RandomAccessFile`
  - method `FileChannel getChannel()`
  - since Java 7 also `FileChannel.open(Path....)`
- `java.nio.channels.Channels`
  - methods for creation of Readers and Writers from channels

Usage

- java.nio.ByteBuffer
  - only possibility for communication with a channel

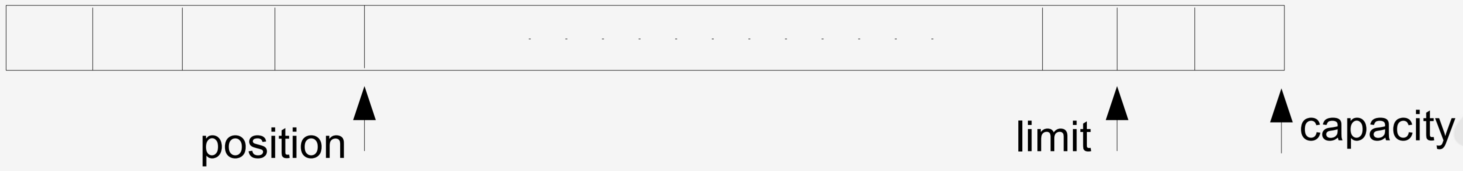
```
FileChannel fc =
     new FileOutputStream("data.txt").getChannel();
fc.write(ByteBuffer.wrap("Some text ".getBytes()));
fc.close();

fc = new FileInputStream("data.txt").getChannel();
ByteBuffer buff = ByteBuffer.allocate(1024);
fc.read(buff);
buff.flip();
while(buff.hasRemaining())
  System.out.print((char)buff.get());
```

Buffer creation

- ByteBuffer.wrap(byte[] b)
  - static method
  - creates a buffer from an array of bytes
  - buffer is interconnected with the array
  - buffer capacity = b.length
- ByteBuffer.allocate(int capacity)
  - static method
  - allocates an empty buffer with specified capacity
- ByteBuffer.allocateDirect(int capacity)
  - static method
  - allocated buffer is “more” tied with OS
    - usage of the buffer should be faster
    - depends on OS

Buffer

- capacity
  - how many elements buffer contains
  - cannot be increased
- limit
  - index of the first element that will not be read or written
  - cannot be bigger than capacity
- position
  - index of the first element that will be written or read on a following operation
  - cannot be bigger than limit



Buffer: methods

- flip()
  - sets the limit to the current position and
  - sets the position to 0
- clear()
  - sets the limit to the capacity and
  - sets the position to 0
- mark()
  - sets the mark to the current position
- reset()
  - sets the position to the mark
  - does not remove the mark
- rewind()
  - sets the position to 0 and removes the mark

Copying between channels

- methods transferTo() and transferFrom()

```
public static void main(String[] args) throws Exception {

  FileChannel
    in = new FileInputStream(args[0]).getChannel(),
    out = new FileOutputStream(args[1]).getChannel();

  in.transferTo(0, in.size(), out);

  // or:
  // out.transferFrom(in, 0, in.size());
}
```

Using buffer

- views on buffers
- reading and writing primitive types
- methods on the ByteBuffer
  - asCharBuffer()
  - asDoubleBuffer()
  - asFloatBuffer()
  - asIntBuffer()
  - asLongBuffer()

```
ByteBuffer bb = ByteBuffer.allocate(1024);
bb.asIntBuffer().put(1234);
System.out.println(bb.getInt());
```

Endian

- by default the `ByteBuffer` uses *big endian*
- can be changed to *little endian*
  - method `order(ByteOrder b)`
  - the class ByteOrder has to static attributes of the type ByteOrder
    - BIG_ENDIAN
    - LITTLE_ENDIAN

Files mapped to the memory

- accessing a file like an array in memory
- method on a channel
  - MappedByteBuffer map()

```
public class LargeMappedFiles {
  static int length = 0x8FFFFFF; // 128 Mb
  public static void main(String[] args) throws Exception {
    MappedByteBuffer out =
      new RandomAccessFile("test.dat", "rw").getChannel()
      .map(FileChannel.MapMode.READ_WRITE, 0, length);
    for(int i = 0; i < length; i++)
      out.put((byte)'x');

    for(int i = length/2; i < length/2 + 6; i++)
      System.out.print((char)out.get(i));
  }
}
```

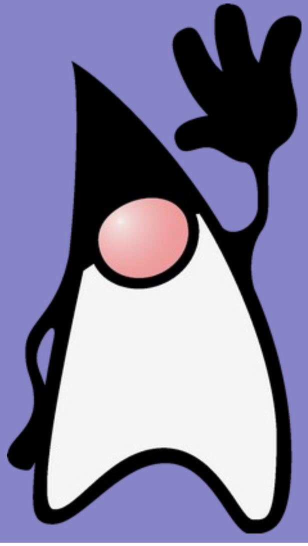
File locking

```
FileOutputStream fos = new FileOutputStream("file.txt");
FileLock fl = fos.getChannel().tryLock();
if (fl != null) {
  System.out.println("File locked.");
  Thread.sleep(100);
  fl.release();
  System.out.println("File unlocked");
}
fos.close()
```

- exact behavior depends on OS
- only a part of file can be locked
- lock() – waits until a file is locked
- tryLock() – does not wait

Input/Output

… back to Path/Files

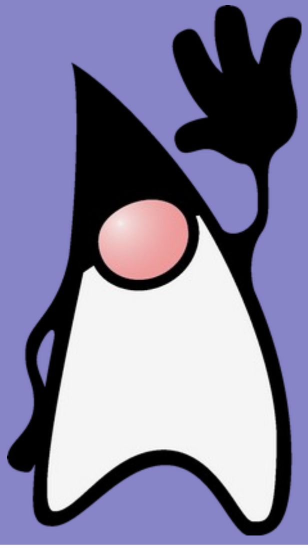


Opening files

- methods of Files
  - BufferedReader newBufferedReader(Path p, Charset cs)
  - BufferedWriter   newBufferedWriter(Path p, Charset cs, OpenOption... opts)
  - InputStream newInputStream(Path p, OpenOption... opts)
  - OutputStream newOutputStream(Path p, OpenOption... opts)
  - SeekableByteChannel newByteChannel(Path p, OpenOption... opts)
  - DirectoryStream<Path> newDirectoryStream(Path dir)
  - ...

Input/Output

Console

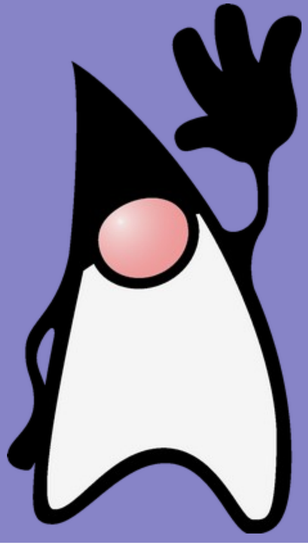


Console

- access to the char console
  - not always available
- System.console()
  - obtaining the console
- Console printf(String format, Object... args)
  - as printf() in C
- String readLine()
  - returns a line (without the new line char at the end)
- char[] readPassword()
  - returns a line (without the new line char at the end)
  - typed characters are not shown
- Reader reader()
- PrintWriter writer()
  - returns reader/writer associated with the console

Input/Ouput

Compression



Overview

- package java.util.zip
- compression via filters
  - FilterInputStream and FilterOutputStream
- CheckedInputStream, CheckedOutputStream
  - provides check-sums of read/written data
- InflaterInputStream, DeflaterOutputStream
  - basic classes for compression and decompression
- GZIPInputStream, GZIPOutputStream
  - compression in the GZIP format
- ZipInputStream, ZipOutputStream
  - compression in the ZIP format

GZIP

- compression of a single file
- compatible with the UNIX programs gzip and gunzip

```
BufferedInputStream in = new BufferedInputStream(
  new FileInputStream(args[0]));
BufferedOutputStream out = new BufferedOutputStream(
   new GZIPOutputStream(
      new FileOutputStream("test.gz")));
int c;
while((c = in.read()) != -1)
  out.write(c);
in.close();
out.close();
```

ZIP

- compression of multiple files into a single archive
- compatible with ZIP programs
- creating an archive
  - `ZipOutputStream`
  - the method `putZipEntry(ZipEntry ze)`
    - next file to the archive
  - the class `ZipEntry`
    - name of the file
    - information about the file (size before/after compression, comment, check-sum,...)
- reading from an archive
  - `ZipInputStream`
    - the method `getNextEntry()`
  - `ZipFile`
    - the method `entries() –` returns `Enumeration`

ZIP

```
ZipOutputStream zos = new ZipOutputStream(
     new BufferedOutputStream(new FileOutputStream("test.zip")));
zos.setComment("Test ZIP");
for(int i = 0; i < args.length; i++) {
  System.out.println("Storing a file: " + args[i]);
  BufferedInputStream in = new BufferedInputStream(
    new FileInputStream(args[i]));
  zos.putNextEntry(new ZipEntry(args[i]));
  int c;
  while((c = in.read()) != -1)
    zos.write(c);
  in.close();
}
zos.close();
```