Java course - IAG0040

I/O, Files & Streams

Anton Keks 2011

File System

- **java.io.File** provides system-independent view of hierarchical pathnames (immutable)
  - `File f = new File("/bin");`
    `f = new File(f, "ping");`
- Can be used to represent files or directories
  - check for existence and permissions
  - query various info (length, attributes)
  - Create, rename or delete both files and directories
  - static fields provide quick access to system-dependent separators: `File.separator`, `File.pathSeparator`

- '/' works on all platforms, including Windows

File System Tips

- How to avoid dealing with separators
  - `File parent = new File("someDir");`
  - `File subdir = new File(parent, "bin");`
- Obtain a valid temporary file
  - `File tmpFile = File.createTempFile("something", ".tmp");`
  - `tmpFile.deleteOnExit();`
- Enumerate Windows drives
  - `File[] roots = File.listRoots();`
  - `File unixRoot = roots[0];`
- Enumerate files in a directory

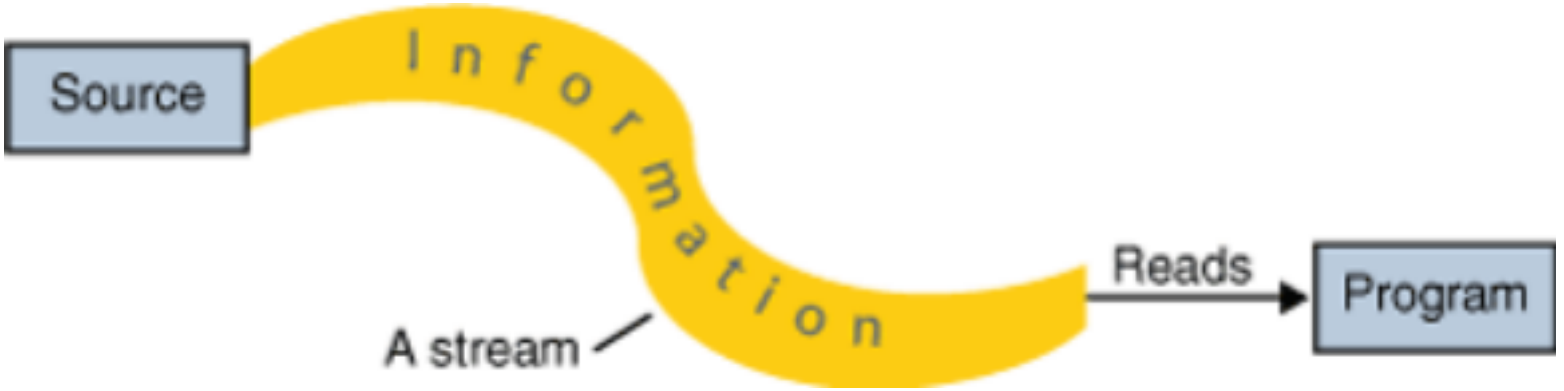
Random Access

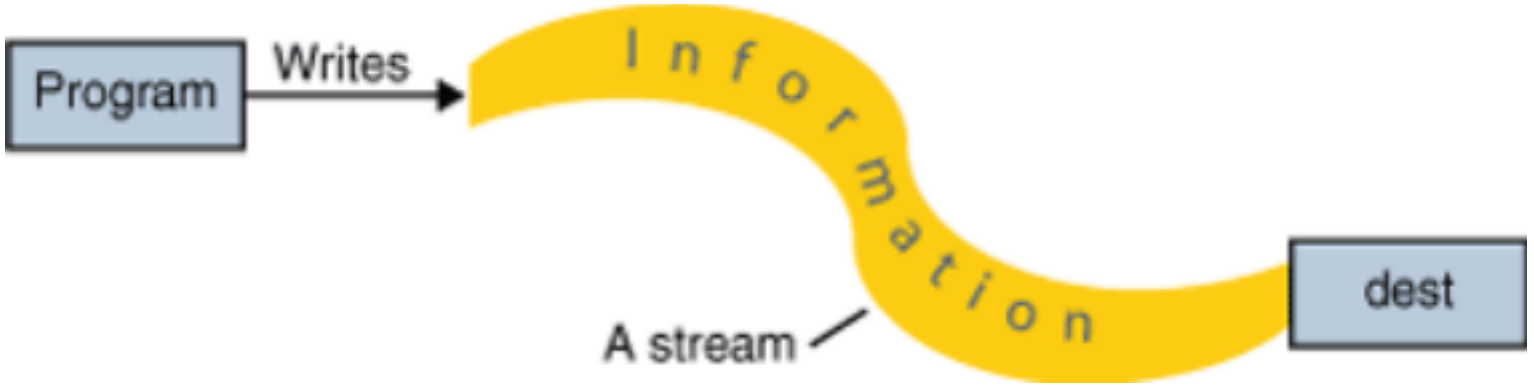
- java.io.RandomAccessFile
  - is used when streams are not suitable, e.g. random access of large binary files
  - like a large array of bytes in the file system
  - both reading and writing is possible (depending on mode)
- Has a file pointer that can be read and moved - `getFilePointer()`, `seek()`
- Reading/writing methods are very similar to various

Input/OuputStreams

- even `DataInput` and `DataOutput` are implemented

I/O as Streams





I/O and Streams

- Java provides I/O facilities in 2 packages
  - **java.io** - traditional synchronous stream-based I/O
  - **java.nio** - 'new' (a)synchronous block-based I/O
- I/O is about reading and writing data
- Reading and writing is possible using **Streams**
  - **Streams** are processed sequentially
  - **Streams** are independent of nature of data
- Java provides

two types (hierarchies) of Streams
- Byte streams (binary)
- Character streams (unicode text)

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processing

Reading **Writing**

Basic Stream

- open a stream (defines the source)
- while more information
  - read information
- close the stream

Provided by:

- java.io.InputStream
- java.io.Reader

- open a stream (defines the destination)
- while more information
  - write information

- close the stream

- java.io.Writer

Provided by:

- java.io.OutputStream

Basic operations

- Reader and InputStream
  - `int read()` - reads a single byte/character (returned as int)
  - `int read(byte/char buf[])` - reads as many bytes as possible into the passed array, returns number of bytes read
  - `int read(byte/char buf[], int offset, int length)` - the same, but works with the specified portion of an array
  - In addition, both support marking locations within a stream, skipping input data, and resetting current position

- Writer and OutputStream
  - `void write(...)` methods are analogous with reading
  - `void flush()` - flushes all buffered data to the output (if any)

Opening and Closing

- Streams are automatically opened on creation - If you have a stream instance - it is ready for reading or writing
- Closing is explicit
  - `close()` method closes the stream
  - `flush()` is implicit during closing of output streams

- Frees all underlying resources
- Is not the same as object destruction
- Always call it as early as possible
- After `close()` is called, any reads or writes will fail
- Closing several times is safe

IOException

- I/O classes throw checked *IOExceptions*
- Used by both **java.io** and **java.nio**
- There are many more specific derived

exceptions, like *FileNotFoundException*, *EOFException*, *CharacterCodingException*, etc

- Even the `close()` method can throw an *IOException* (unfortunately)
  - Leads to TCFTC (try-catch-finally-try-catch)

Stream classification

- **Direction:** input and output
- **Data type:** binary and character
- Sink streams or 'endpoints'

- *FileInputStream*, *ByteArrayInputStream*, *StringReader*, etc

- Processing streams (wrappers)
  - Base classes: *FilterInputStream*, *FilterOutputStream*, *FilterReader*, *FilterWriter*
  - *SequenceInputStream*, *ObjectInputStream*, *BufferedInputStream*, *LineNumberReader*, etc
- Bridges from binary to characters
  - *InputStreamReader*, *OutputStreamWriter*

In-memory I/O

- These streams operate on in-memory data structures, which are passed to them on

creation

- *ByteArrayInputStream*, *ByteArrayOutputStream*
- *CharArrayReader*, *CharArrayWriter*
- *StringReader*, *StringWriter*
- *StringBufferInputStream* (deprecated)

- Useful for mocking streams

File I/O

- Reading files

- *FileInputStream* – reads binary files
- *FileReader* – reads text files using the default encoding

- *InputStreamReader* can be used for other encodings

Writing files

- *FileOutputStream* – writes binary files
- *FileWriter* – writes text files using the default encoding

- Task:
  - write a simple 'copy' program (*SimpleCopyProgram* class), implement *net.azib.java.lessons.io.FileCopier*

Buffering

- These streams wrap other streams to provide buffering capabilities
  - *BufferedInputStream*, *PushbackInputStream*
  - *BufferedOutputStream*
  - *BufferedReader*, *PushbackReader*
  - *BufferedWriter*
- Task:
  - write *BufferedCopyProgram* (implementing *FileCopier*)
  - measure performance of both implementations with `System.currentTimeMillis()`

Formatted printing

- Provide convenient printing (e.g. to the console, file, another *Writer*, or *OutputStream*)
- Write-only
  - *PrintWriter* (is preferred)
  - *PrintStream* (*System.out* and *System.err*)
- Often other writable streams are wrapped into these
- They do internal buffering, either a newline char or special method invocations automatically flush the data in case *autoFlush* is enabled
- Warning: *IOExceptions* are never thrown out!
  - `checkError()` may be used for error checking

Misc features

- Concatenation:
  - *SequenceInputStream* – allows to concatenate multiple *InputStreams* together
- Pipes:
  - *PipedInputStream*, *PipedOutputStream*, *PipedReader*, *PipedWriter* – allows to connect *InputStream* to an *OutputStream*
- Counting:
  - *LineNumberReader* – counts line numbers while reading
- Peeking ahead:
  - *PushbackInputStream* and *PushbackReader* – allows to return read data back to stream
- Arbitrary data:

- *DataInputStream, DataOutputStream* – allows to read/write primitive types easily

Serialization

- Java natively supports serialization of data (persistent storage of objects' internal state)
  - Serialization: *ObjectOutputStream*
  - Deserealization: *ObjectInputStream*
- Interfaces
  - *Serializable* – marker but has some methods documented
  - *Externalizable* – defines methods for saving/restoring data manually during the serialization
- It is highly recommended to define `static final long serialVersionUID` field in serializable classes (used for compatibility checks), otherwise it is computed automatically

- fields, declared as **transient** or **static**, are not serialized - Can be used for **deep** cloning, faster than cloning recursively

Channels and Buffers

- **java.nio** offers a new way for I/O: Channels and Buffers
  - All data operations are performed on Buffers (data blocks)
    - There are buffers for all primitive types, like *ByteBuffer*, *LongBuffer*, *FloatBuffer*, etc
    - Buffers are allocated using their static methods
    - Buffers are internally arrays, which maintain their capacity, limit, and position, thus simplifying writing code

- Channels are like Streams, but they are bi-directional and read or write data from/into Buffers only. No direct access to data is possible.

Buffers

- All buffers are mutable
- *ByteBuffer* is most used, provides methods for reading/writing all other primitive types, absolute (index-based) and relative (current position based)
- *ByteBuffer* provides views as other buffers, e.g. IntBuffer, FloatBuffer
- Direct buffers are backed by OS native storage if possible, non direct buffers are Java arrays

`ByteBuffer.allocate()` - allocates a non-direct buffer
`ByteBuffer.allocateDirect()` - allocates a direct buffer `ByteBuffer.wrap()` - wraps an existing Java array

`clear()` prepares buffer for reading (discards previous content) `flip()` prepares buffer for writing after it was used for reading

Channels

- A channel is an open connection used for reading/writing of data contained in Buffers
- Channels static class provides utility methods for

bridging **java.io** Streams and **java.nio** Channels

- ReadableByteChannel, WritebleByteChannel, and ByteChannel operate on ByteBuffers
- ScatteringByteChannel and GatheringByteChannel operate on arrays of buffers (useful when reading fixed length heterogeneous data sequentially)

FileChannel

- Can be obtained with `getChannel()` either from *FileInputStream*, *FileOutputStream*, or

RandomAccessFile (read-only, write-only, and read write respectively)

- Provides file locking and file portion locking with `lock()` methods
- Provides memory mapping with map() methods
  - Memory mapped I/O maps files (whole or in parts) directly to the memory to speed up random reads/writes
- "Advanced" features depend on the support from the underlying OS

Channels and Buffers Task

- Write some more 'copy' functionality
  - With non-direct buffer
  - With direct buffer
  - With memory-mapped I/O
- Measure performance of these and the ones written before
  - Stream based
  - Buffered stream based
- Implement everything as implementing the *FileCopier* interface
- Input file, output file, and copying method should be specifiable on the command-line
- Write unit tests (you can use `File.createTempFile()` method)

Asynchronous I/O

- **java.nio** provides APIs for asynchronous I/O
  - All other I/O in Java is synchronous (blocking)
- Channels, extending the abstract *SelectableChannel*, can work asynchronously
- *Selector* is a multiplexor, obtained using `Selector.open()`
- *SelectionKey* represents a *SelectableChannel's* registration with a *Selector*
- *SelectableChannel* provides several `register()` methods for registering itself with a *Selector* for particular events
  - `configureBlocking()` is used for enabling asynchronous mode
- `selector.select()` is then used for waiting for registered events