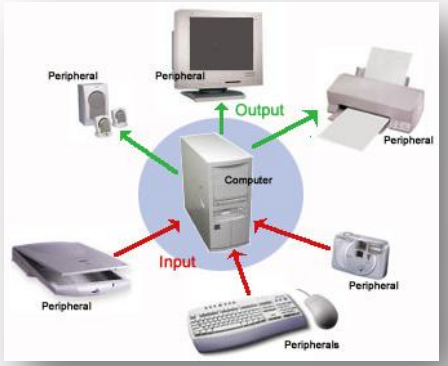
Handling I/O in Java

Techniques , Gotchas & Best Practices

Overview & Techniques

What is I/O?

Communication between the computer and the outside world

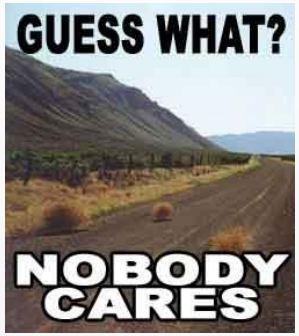


What's in the Outside World?

- Human users
- Hardware devices
  - Monitors, keyboards, disk drives …
- Other computers and programs

Why Should We Care?

- An essential part of most programs
- Computers spend a lot of time performing nothing but I/O operations
- Very complicated business to deal with
- Ranks No.1 in the performance killer list



What are the Different Types of I/O?

- Console I/O
- Keyboard I/O
- File I/O
- Network I/O
- …and possibly more

How Does Java Support I/O?

- The Java I/O API
  - The `java.io` package
  - Since JDK 1.0
  - Extensible

Stream

http://natureadore.blogspot.com/p/stream.html

Reading and Writing with Streams

```
InputStream in = openInputStream();
int b = in.read();

byte[] data = new byte[1024];
int len = in.read(data);

OutputStream out = openOutputStream();
out.write(b);
Out.write(data, 0, len);
```

Readers and Writers

- Utilities for reading and writing **character** streams

```
Reader reader = getReader();
int ch = reader.read();

char[] data = new char[1024];
int len = reader.read(data);

Writer writer = getWriter();
writer.write(ch);
writer.write(data, 0, len);
```

Bridging the Gap Between Bytes and Characters

```
InputStream in = openInputStream();
Reader reader = new InputStreamReader(in, “UTF-8”);

OutputStream out = openOutputStream();
Writer writer = new OutputStreamWriter(out, “UTF-8”);
```

Reading and Writing Typed Data

- Utilities to read primitive data and strings

```
DataInputStream in = new
  DataInputStream(openInputStream());
float num = in.readFloat();

DataOutputStream out = new
  DataOutputStream(openOutputStream());
out.writeFloat(num);
```

Buffered Vs Unbuffered

- Unbuffered – Each I/O request to the stream is directly handled by the underlying OS.
- Buffered – Each I/O request to the stream is executed on an in-memory buffer. OS invoked only when the buffer is empty.

Buffered I/O

```
InputStream in = new
  BufferedInputStream(openInputStream());
OutputStream out = new
  BufferedOutputStream(openOutputStream());


BufferedReader reader = new
  BufferedReader(getReader());
BufferedWriter writer = new
  BufferedWriter(getWriter());
```

Problems with Streams

- Old school
- Slow
- Blocking

http://www.flickriver.com/photos/shazral/3565328977/

Alternatives?

- The Java New I/O (NIO) API
  - The `java.nio` package
  - Introduced in JDK 1.4
  - Leverages most efficient I/O operations of the underlying OS
  - Support for multiplexed, non-blocking I/O

Buffers

- A contiguous block of memory used to read and write bytes
- Memory can be allocated in a manner so that the underlying OS can directly access it (Direct buffers)

Reading and Writing with Buffers

```
byte[] src = getData();
ByteBuffer buf =
  ByteBuffer.allocateDirect(1024);
buf.put(src);

byte[] dest = new byte[1024];
buf.flip();
buf.get(dest);
```

Channels

- Represents an open connection to an I/O device
- Facilitates efficient bulk data transfers between devices and buffers
- A channel instance can be obtained from a class of the standard I/O package

Reading from a Channel

```
FileInputStream fin = new
   FileInputStream("config.xml");
FileChannel channel = fin.getChannel();
ByteBuffer buffer =
   ByteBuffer.allocateDirect(1024);
while (true) {
   buffer.clear();
   int len = channel.read(buffer);
   if (len == -1) {
       break;
   }
   buffer.flip();
   ...
}
```

Direct Channel Transfers

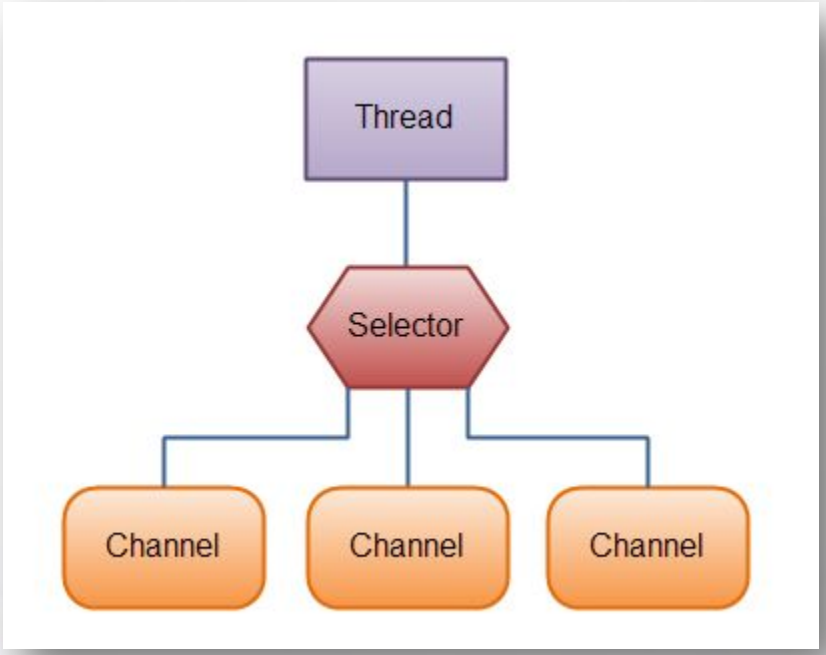
```
FileChannel in = new
  FileInputStream(source).getChannel();
FileChannel out = new
  FileOutputStream(target).getChannel();
in.transferTo(0, in.size(), out);
```

Memory Mapped Files

```
FileInputStream input = new
  FileInputStream(filename);
FileChannel channel = input.getChannel();
int fileLength = (int)channel.size();
MappedByteBuffer buffer =
  channel.map(FileChannel.MapMode.READ_ONLY,
  0, fileLength);
```

Multiplexed I/O with Selectors

- A mechanism to register for I/O events on multiple channels and wait until at least one event occurs



http://tutorials.jenkov.com/java-nio/selectors.html

Registering for I/O Events

```
Selector selector = Selector.open();
channel1.register(selector,
  SelectionKey.OP_CONNECT |
  SelectionKey.OP_READ);
channel2.register(selector,
  SelectionKey.OP_CONNECT);
channel3.register(selector,
  SelectionKey.OP_WRITE);
```

‘Selecting’ a Channel

```
while (selector.select(500) > 0) {
   Set readyKeys = selector.selectedKeys();
   …
}
```

Non-blocking I/O

- Channels generally block until the I/O operations are complete (similar to streams)
- But some channel implementations can be made to work in a non-blocking manner

```
SocketChannel ch = SocketChannel.open();
ch.configureBlocking(false);
```

Standard I/O Vs. NIO

- A small demonstration…

NIO 2.0

- Introduced in JDK 1.7
- Even better support for file manipulation
  - Path, FileAttribute
  - Tree walk, File watch
- Asynchronous I/O

Hiranya's Laws for Proper I/O Handling

By a Developer for the Developers

Clean up your mess

Always close your streams and channels when you are done with them

Buffering can be both your friend and enemy

Don’t blindly wrap all streams with their buffered counter parts. Buffering can yield good performance if you’re doing a lot of small I/O operations. Otherwise it only contributes to increased memory consumption.

Don’t forget to flush after you!

If you’re using any buffered streams, make sure to flush them out before closing the streams. Failing to do so may result in data loss.

There’s no escape from Karma and IOException

Developers often tend to ignore certain I/O exceptions thinking that they will never be thrown. But be aware that all I/O operations are prone to errors and may throw an exception at any time.

Java is platform independent – I/O is not

You need to do some additional work to make your I/O handling code truly platform independent. Use the java.io.File abstraction instead of strings to deal with files. Don’t make any assumptions about how the underlying OS handles certain I/O operations.

Concurrency and I/O Don’t Go Together

In a multi-user or multi-threaded environment, make sure that individual I/O operations are properly isolated. Attempting to access the same file or channel with concurrent threads can lead to disasters.

Nothing is perfect – Not even NIO

NIO is generally faster, but might not yield a significant performance gain in some scenarios. NIO code has a tendency to become complex and difficult to understand. Also note that NIO is still an evolving technology.

Best way to write good I/O code is to not write them

Use existing utilities and libraries that specialize in I/O handling.

Apache Commons IO

- A quick peek at the API and a demo

Questions?

Thank You