Principles of Software Construction: Objects, Design and Concurrency

Design Case Study: Stream I/O

15-214

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Learning Goals

- Understand the design aspects of the Stream abstractions in Java
- Understand the underlying design patterns
  - Adapter
  - Decorator
  - Template Method
  - Iterator

Design Challenge

- Identify a generic and uniform way to handle I/O in programs
  - Reading/writing files
  - Reading/writing from/to the command line
  - Reading/writing from/to network connections
- Reading bytes, characters, lines, objects, …
- Support various features
  - Buffering
  - Encoding (utf8, iso-8859-15, …)
  - Encryption
  - Compression
  - Line numbers
- Refer to files
  - Paths, URLs, symbolic links, directories, files in .jar containers, searching, …

Streams and Readers

The Stream abstraction

- A sequence of **bytes**
- May read, 8 bit at a time, and close (see Iterator)

```
java.io.InputStream
   void           close();
   abstract int   read();
   int            read(byte[] b);
```

- May write, flush and close

```
java.io.OutputStream
   void           close();
   void           flush();
   abstract void  write(int b);
   void           write(byte[] b);
```

The Reader/Writer abstraction

- A sequence of **characters** (given a character encoding)
- May read, one by one (see Iterator), and close

```
java.io.Reader
   void          close();
   abstract int  read();
   int           read(char[] c);
```

- May write, flush and close

```
java.io.Writer
   void          close();
   void          flush();
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   void          write(char[] b);
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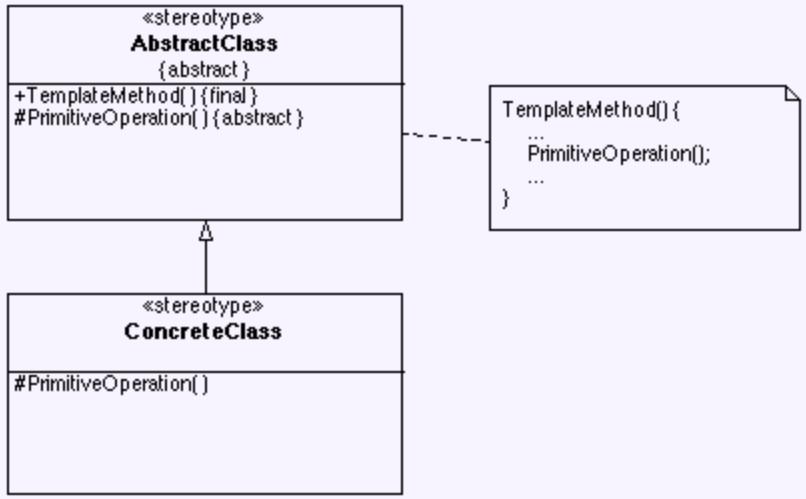
Notice the template method pattern

The *Template Method* design pattern

- Applicability
  - When an algorithm consists of varying and invariant parts that must be customized
  - When common behavior in subclasses should be factored and localized to avoid code duplication
  - To control subclass extensions to specific operations
- Consequences
  - **Code reuse**
  - Inverted "Hollywood" control: don't call us, we'll call you
  - Ensures the invariant parts of the algorithm are not changed by subclasses



You may have used this in your virtual world

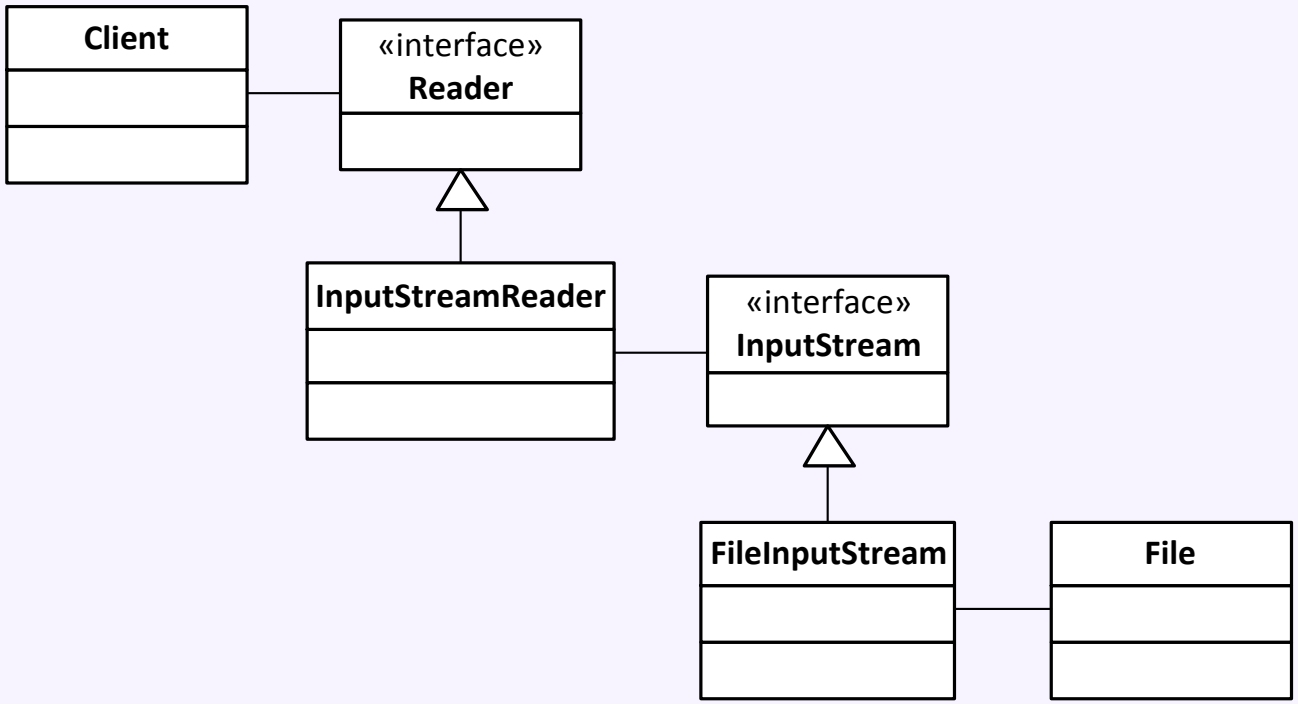
Implementing Streams

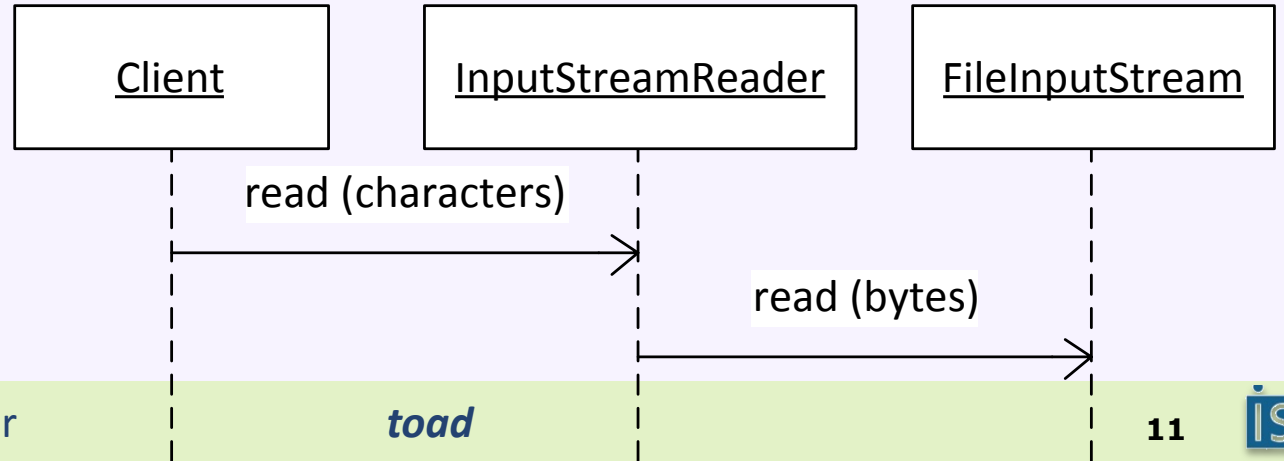
- java.io.FileInputStream
  - reads from files, returns input byte by byte
- java.io.ByteArrayInputStream
  - **Adapter** to provide the stream interface for a byte[] array
- java.io.StringBufferedInputStream
  - **Adapter** to provide the stream interface for a string (deprecated, due to character conversion issues, use Reader instead)
- Many network devices provide streams for URLs, database connections, etc
- java.lang.System.in provides an InputStream for the standard input

Implementing Readers/Writers

- We could provide FileInputReaders and StringReaders and ByteArrayReaders and StandardInputReader, but would replicate functionality of streams
- Instead provide adapter for stream interface; supports streams from arbitrary sources
- java.io.InputStreamReader
  - **Adapter** from any InputStream to Reader (adds additional functionality of the character encoding)
  - Read characters from files/the network using corresponding streams
- java.io.CharArrayReader
  - **Adapter** from char[] array to Reader interface

Readers and Streams

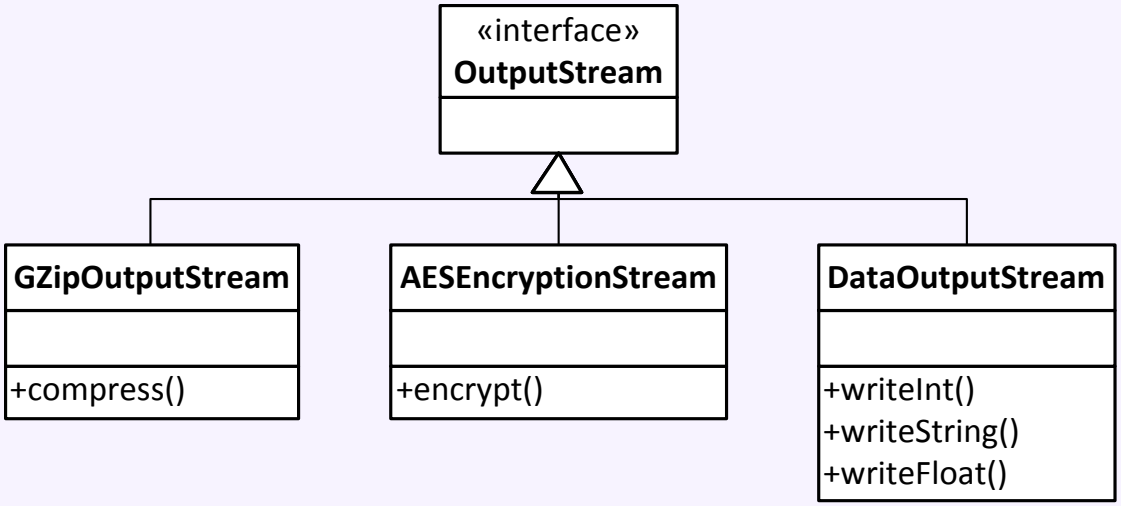


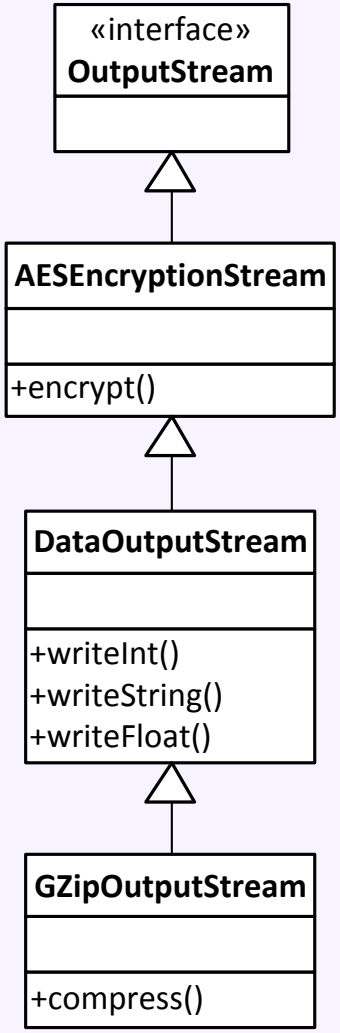


Adding Features

Common Functionality on Streams

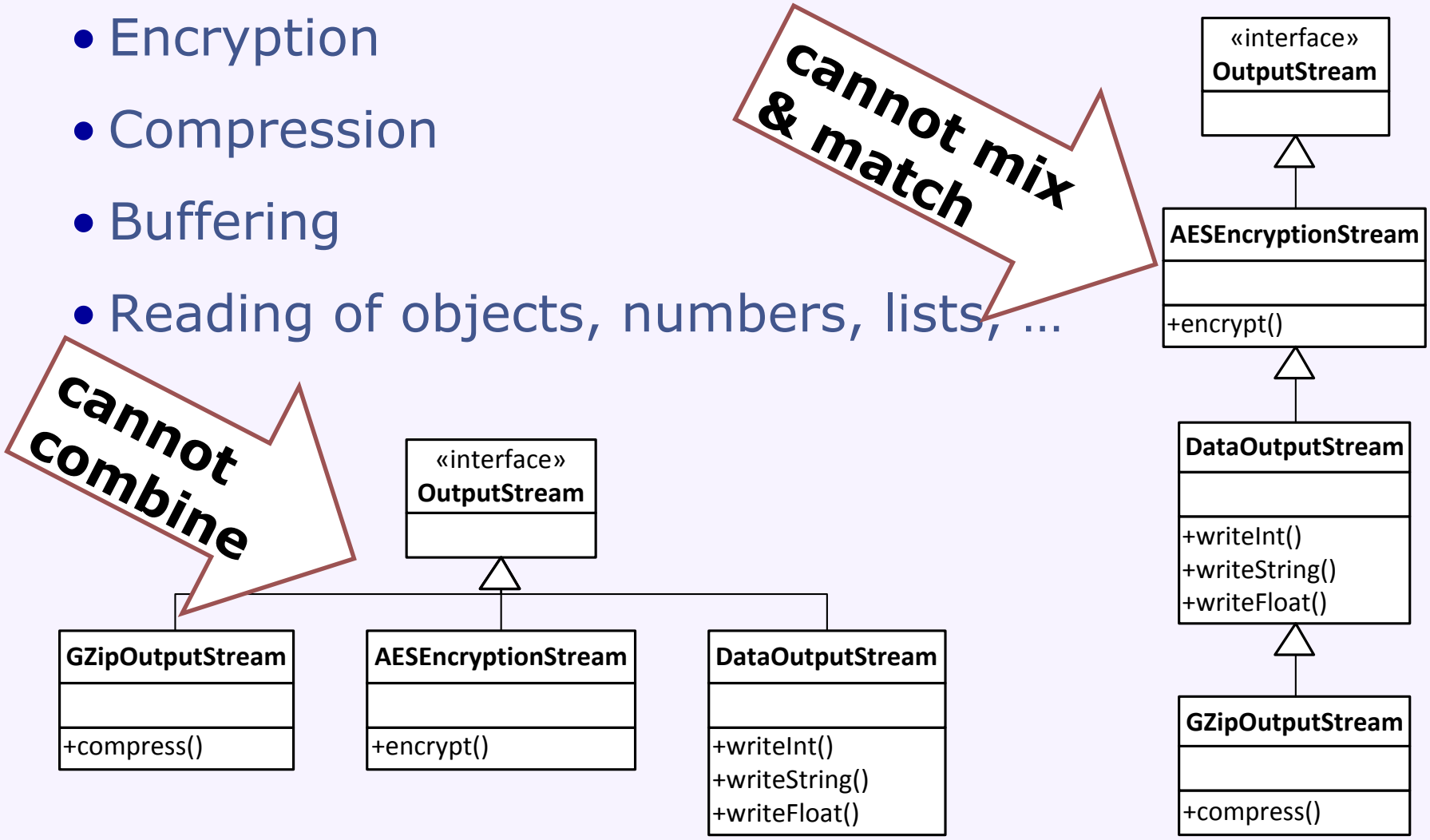
- Encryption
- Compression
- Buffering
- Reading of objects, numbers, lists, …





Common Functionality on Streams

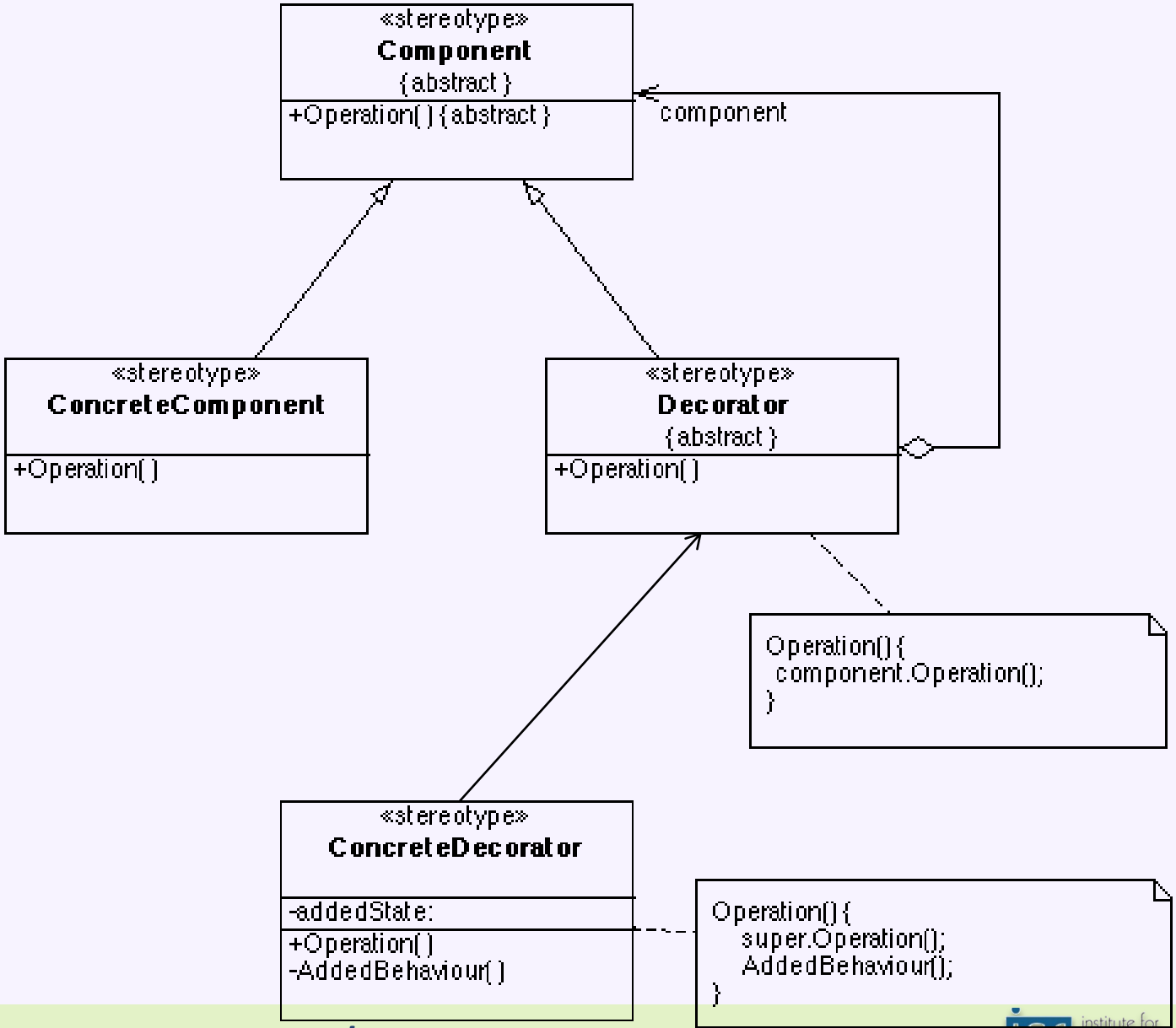
- Encryption
- Compression
- Buffering
- Reading of objects, numbers, lists, …



java.io.DataOutputStream (simplified)

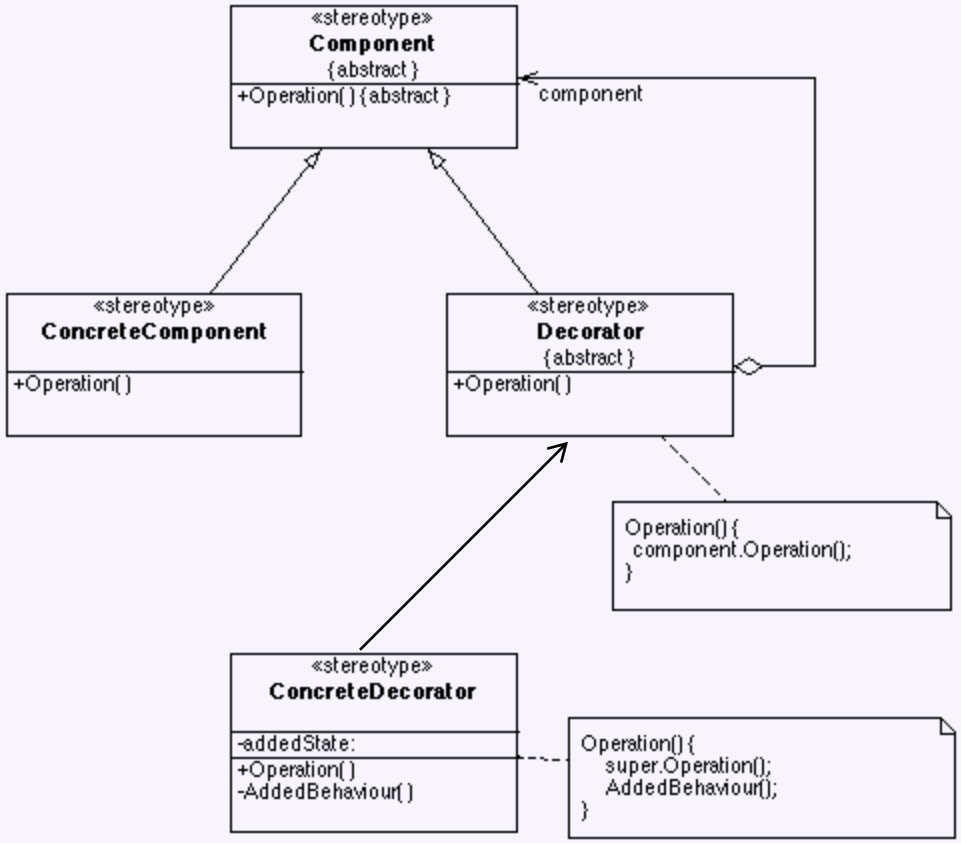
```
class DataOutputStream implements OutputStream {
        private final OutputStream out;
        DataOutputStream(OutputStream o) { this.out=o;}
        public final void writeLong(long v) throws IOException {
                private byte writeBuffer[] = new byte[8];
                writeBuffer[0] = (byte)(v >>> 56);
                writeBuffer[1] = (byte)(v >>> 48);
                writeBuffer[2] = (byte)(v >>> 40);
                writeBuffer[3] = (byte)(v >>> 32);
                writeBuffer[4] = (byte)(v >>> 24);
                writeBuffer[5] = (byte)(v >>> 16);
                writeBuffer[6] = (byte)(v >>> 8);
                writeBuffer[7] = (byte)(v >>> 0);
                out.write(writeBuffer, 0, 8);
                incCount(8);
        }
        public void write(int b) throws IOException { out.write(b); }
        public void flush() throws IOException { out.flush(); }
}
```

The *Decorator* design pattern

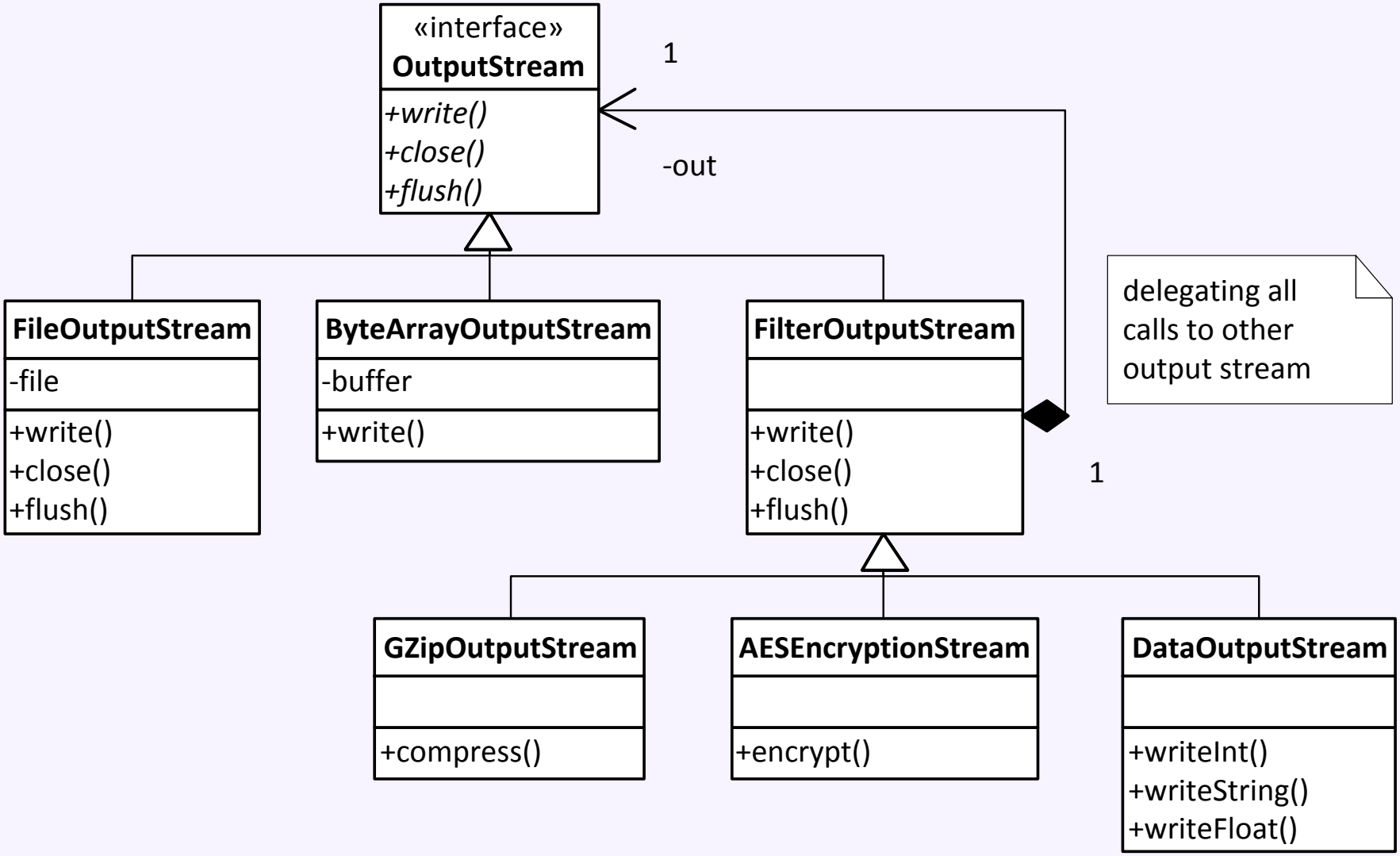


The *Decorator* design pattern

- Applicability
  - To add responsibilities to individual objects dynamically and transparently
  - For responsibilities that can be withdrawn
  - When extension by subclassing is impractical
- Consequences
  - More flexible than static inheritance
  - Avoids monolithic classes
  - Breaks object identity
  - Lots of little objects



Decorator Pattern in OutputStreams



The Scanner observer

- Provides convenient methods for reading from a Stream
- `java.util.Scanner`

```
Scanner(InputStream source);
Scanner(File source);
void    close();
boolean hasNextInt();
int     nextInt();
boolean hasNextDouble();
double  nextDouble();
boolean hasNextLine();
String  nextLine();
boolean hasNext(Pattern p);
String  next(Pattern p);
…
```

- Implements the *Iterator<String>* interface

Summary

- General abstractions for streams and readers
- Many optional features: compression, encryption, object serialization, …
- Flexibility with few base implementations through
  - Adapter pattern
  - Delegation pattern