Principles of Software Construction: Objects, Design, and Concurrency

Design Case Study: Stream I/O

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Administrivia

- No homework due this week
  - Homework 4b due next Tuesday
- TAs have committed to grading Homework 4a by Friday "night"
  - If you want faster feedback to revise your design as you work on Homework 4b, post a Piazza question asking for feedback
    - Please include your Andrew ID in the Piazza note
    - Please ask only if you sincerely need feedback to start Homework 4b

Key concepts from last Thursday

The Iterator design pattern

- Provides a strategy to uniformly access all elements of a container in a sequence
  - Independent of the container implementation
  - Ordering is unspecified, but every element visited once
- The `java.util.Iterator` interface:

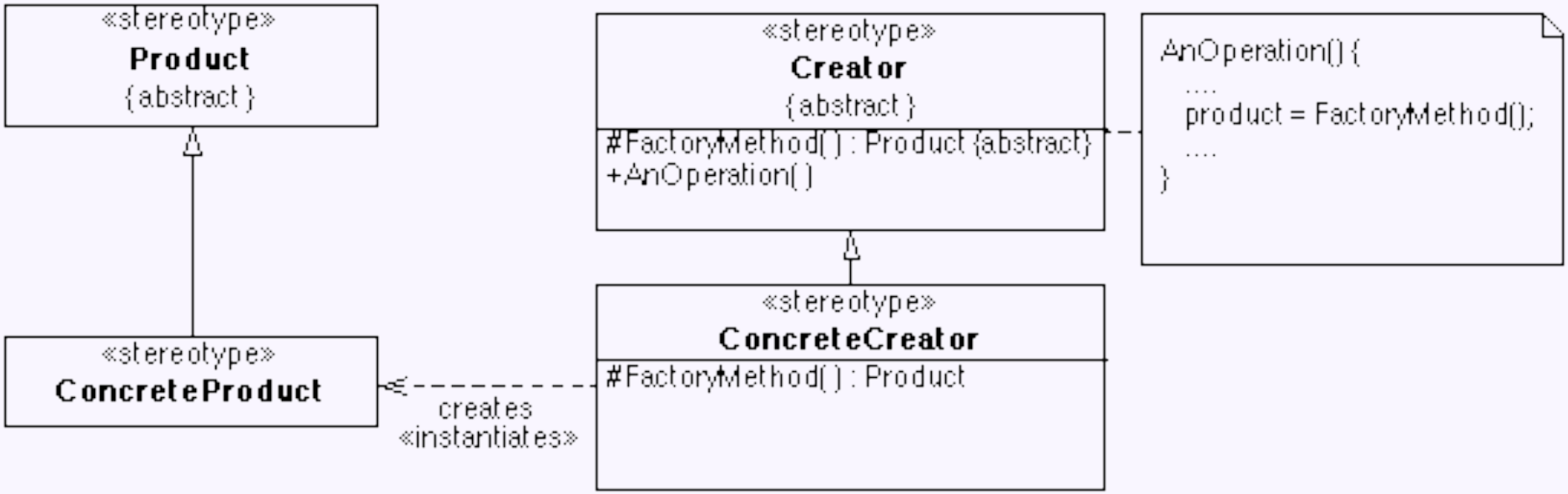
```
public interface java.util.Iterator<E> {
  boolean hasNext();
  E next();
  void remove();  // removes previous returned item
}                 // from the underlying collection
```

Creating Iterators

```
public interface Collection<E> {
  boolean     add(E e);
  boolean     addAll(Collection<E> c);
  boolean     remove(E e);
  boolean     removeAll(Collection<E> c);
  boolean     retainAll(Collection<E> c);
  boolean     contains(E e);
  boolean     containsAll(Collection<E> c);
  void        clear();
  int         size();
  boolean     isEmpty();
  Iterator<E> iterator();
  Object[]    toArray()
  E[]         toArray(E[] a);
  …
}
```

Defines an interface for creating an Iterator, but allows Collection implementation to decide which Iterator to create.

The Factory Method design pattern



Design patterns we have seen so far

Iterator

Composite

Template Method

Adapter

Strategy

Observer

Marker Interface

Decorator

Model-View-Controller

Factory Method

Learning goals for today

- Understand design aspects of the stream abstractions in Java
- Recognize the underlying design patterns:
  - Adapter
  - Decorator
  - Template Method
  - Marker Interface
  - Iterator

A Java aside

- What is a `byte`?
  - Answer: a signed, 8-bit integer (-128 to 127)
- What is a `char`?
  - Answer: a 16-bit Unicode-encoded character

The I/O 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, …

The stream abstraction

- A sequence of **bytes**
- May read 8 bits at a time, and close

```
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** in some encoding
- May read one character at a time 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();
abstract void write(int c);
void          write(char[] b);
```

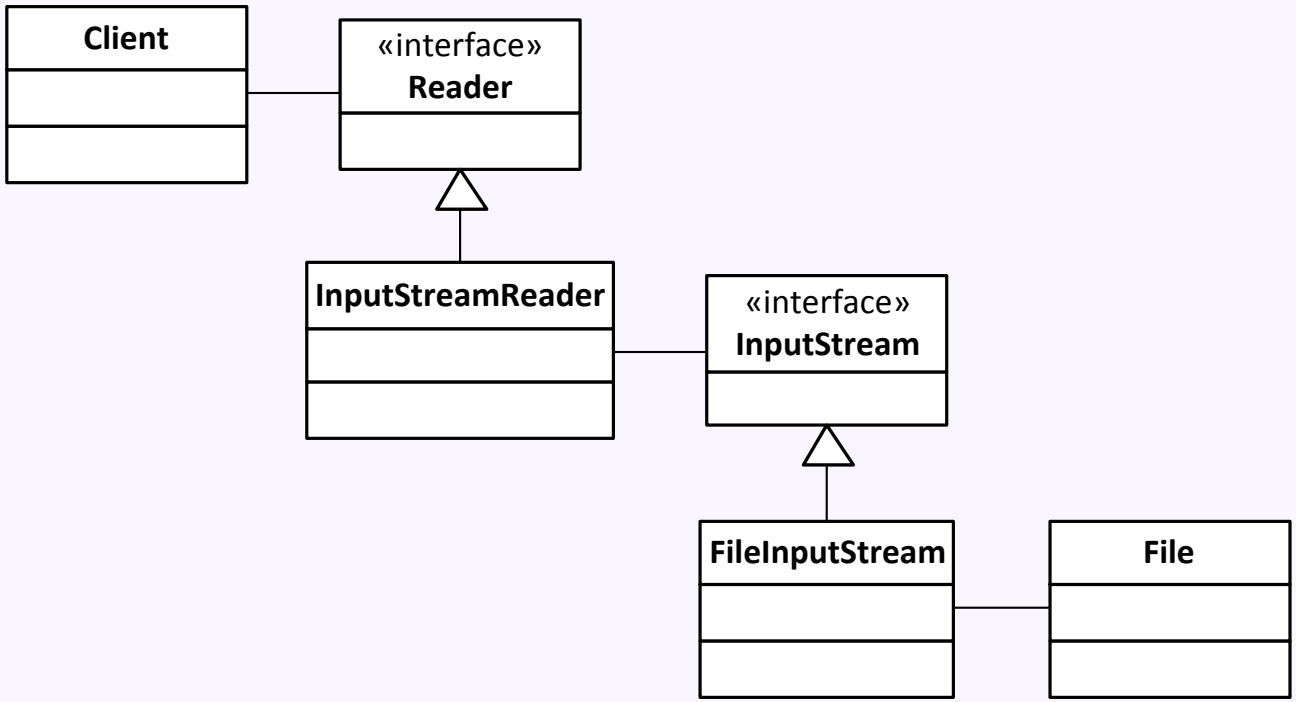
Implementing streams

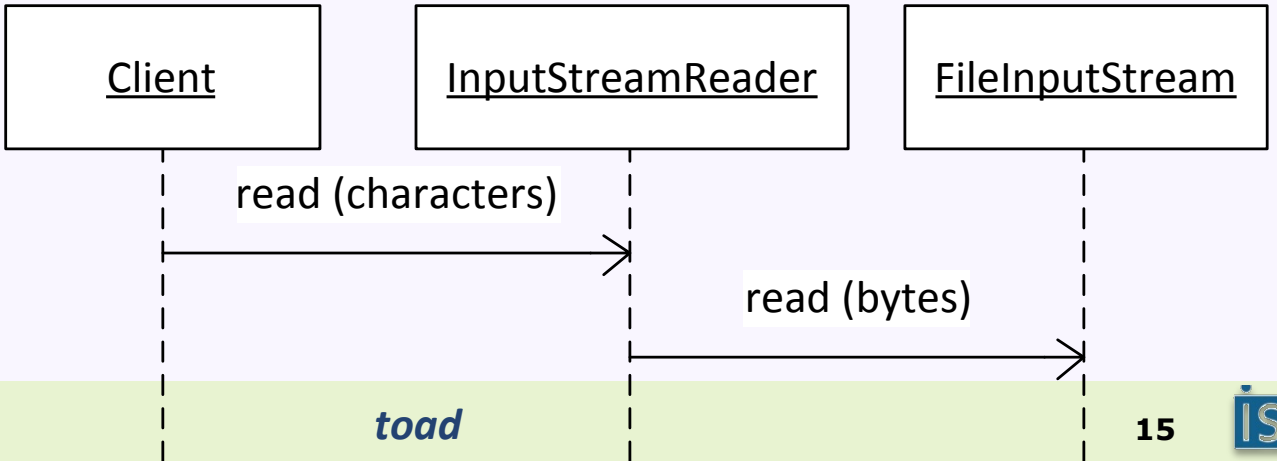
- `java.io.FileInputStream`
  - Reads from files, byte by byte
- `java.io.ByteArrayInputStream`
  - Provides a stream interface for a `byte[]`
- Many APIs provide streams for network connections, database connections, …
  - e.g., `java.lang.System.in`, `Socket.getInputStream()`, `Socket.getOutputStream()`, …

Implementing readers/writers

- `java.io.InputStreamReader`
  - Provides a `Reader` interface for any `InputStream`, adding additional functionality for the character encoding
    - Read characters from files/the network using corresponding streams
- `java.io.CharArrayReader`
  - Provides a `Reader` interface for a `char[]`
- Some convenience classes: `FileReader`, `StringReader`, …

Readers and streams



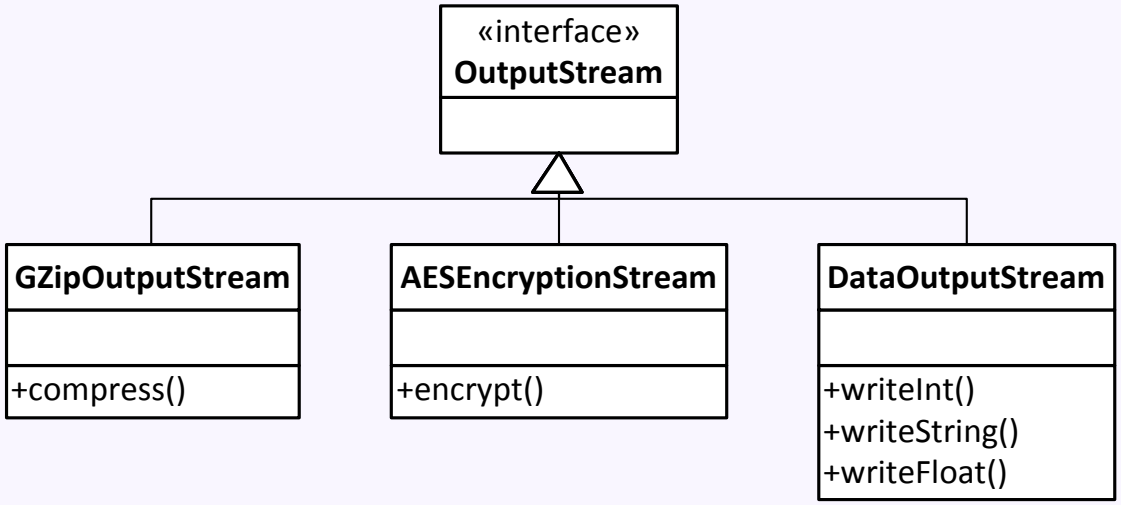


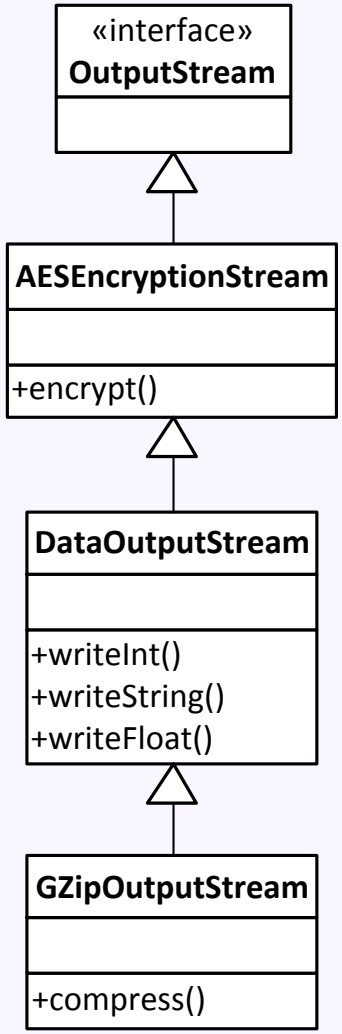
Writers and streams

- See FileExample.java

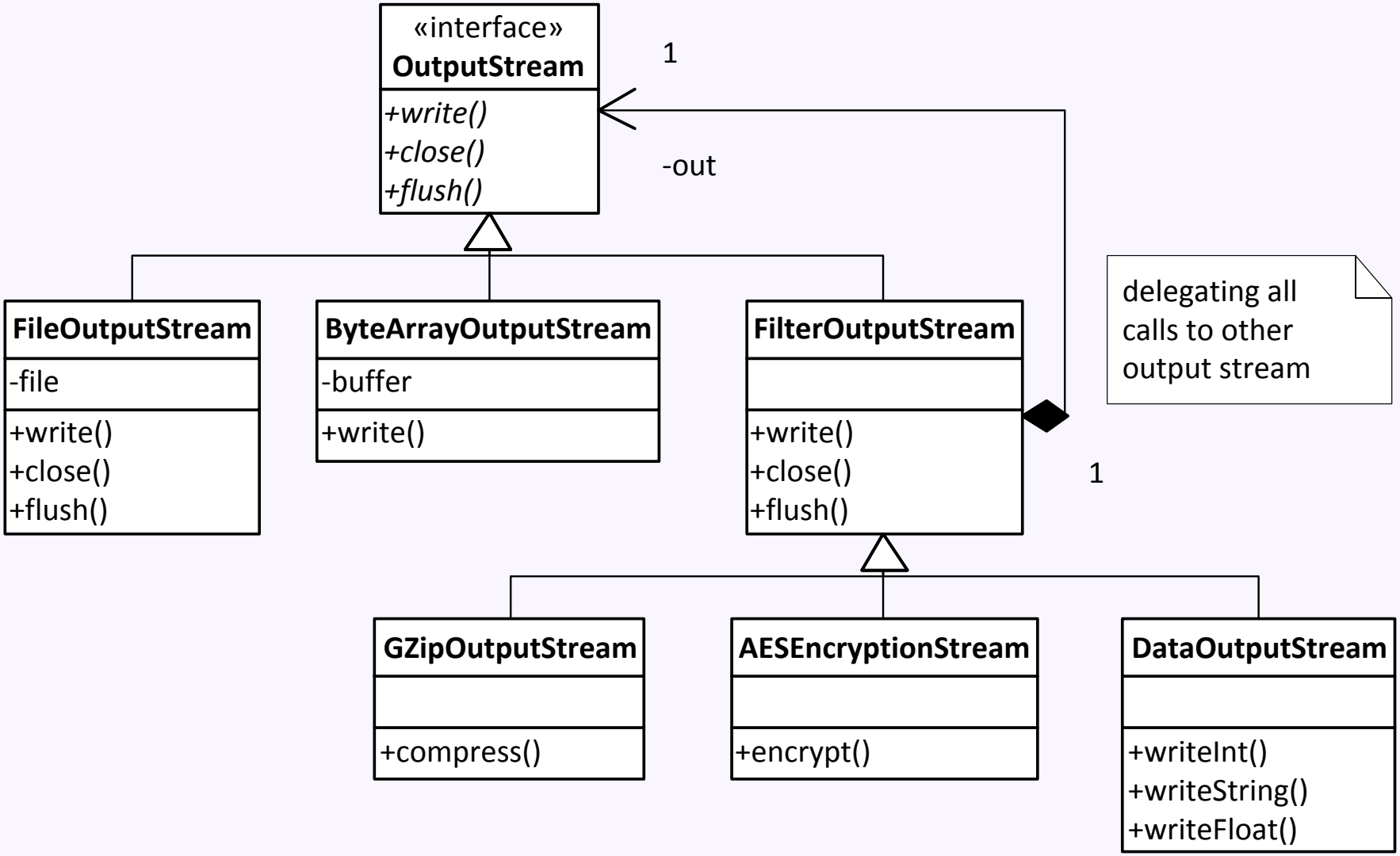
Adding functionality to streams

- E.g. encryption, compression, buffering, reading formatted data such as objects, numbers, lists, …
  - Two possible solutions?:





A better design to add functionality to streams



To read and write arbitrary objects

- Your object must implement the `java.io.Serializable` interface
  - Methods: none
- If all of your data fields are themselves `Serializable`, Java can automatically serialize your class
  - If not, will get runtime `NotSerializableException`
- Can customize serialization by overriding special methods

See QABean.java and FileObjectExample.java

The java.util.Scanner

- 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);
…
```

A challenge for you

- Identify the design patterns in this lecture
  - For each design pattern you recognize, write:
    - The class name
    - The design pattern
    - If you have time: At least one design goal or principle achieved by the pattern in this context
  - Hints:
    - Use the slides online to review the lecture
    - Design patterns include at least:
      - Adapter
      - Decorator
      - Iterator
      - Marker Interface
      - Template Method

Warning: A subtlety of serializability

- Implement `Serializable` judiciously
  - Making a class `Serializable` violates the principle of information hiding
  - (*Effective Java* by Josh Bloch, 2nd edition, p. 274)

Summary

- `java.io` provides general abstractions for streams and readers
  - Standard implementations, convenience implementations
- Many optional features: compression, encryption, object serialization, …
- Convenience and flexibility via the Adapter pattern and Decorator pattern