Binary I/O

Introduction to Programming and Computational Problem Solving - 2

CSE 8B

Lecture 17

Announcements

- Assignment 8 is due today, 11:59 PM
- Final exam is Jun 10, 7:00 PM-9:59 PM
- Course and Professor Evaluations (CAPE)
  - https://cape.ucsd.edu/
  - Must by completed before Jun 4, 8:00 AM
- Reading
  - Liang
    - Chapter 17

Files

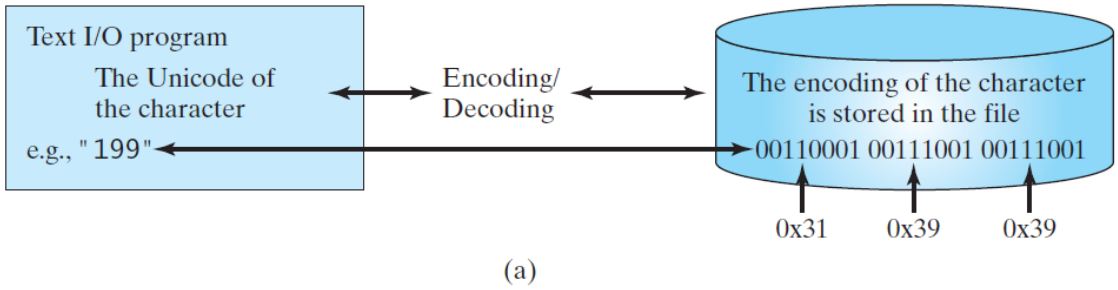
- Files can be classified as either text or binary
  - Human readable files are **text files**
  - All other files are **binary files**
- Java provides many classes for performing text I/O and binary I/O

File I/O

- Remember, a `File` object encapsulates the properties of a file or a path, **but does not contain the methods for reading/writing data from/to a file**
- In order to perform I/O, you need to create objects using appropriate Java I/O classes
  - The objects contain the methods for reading/writing data from/to a file
- Text I/O
  - Use the `Scanner` class for reading text data from a file
    - The JVM converts a file specific encoding to Unicode when reading a character
  - Use the `PrintWriter` class for writing text data to a file
    - The JVM converts Unicode to a file specific encoding when writing a character

Binary I/O

- Binary I/O does not involve encoding or decoding and thus is more efficient than text I/O
- Binary files are independent of the encoding scheme on the host machine



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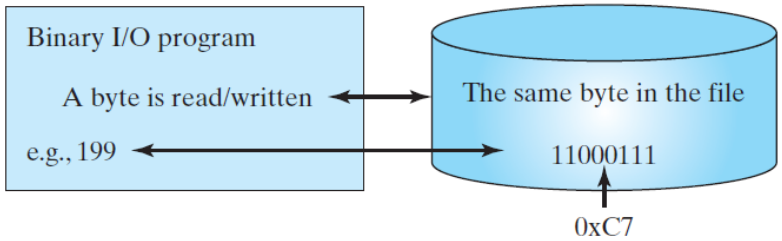

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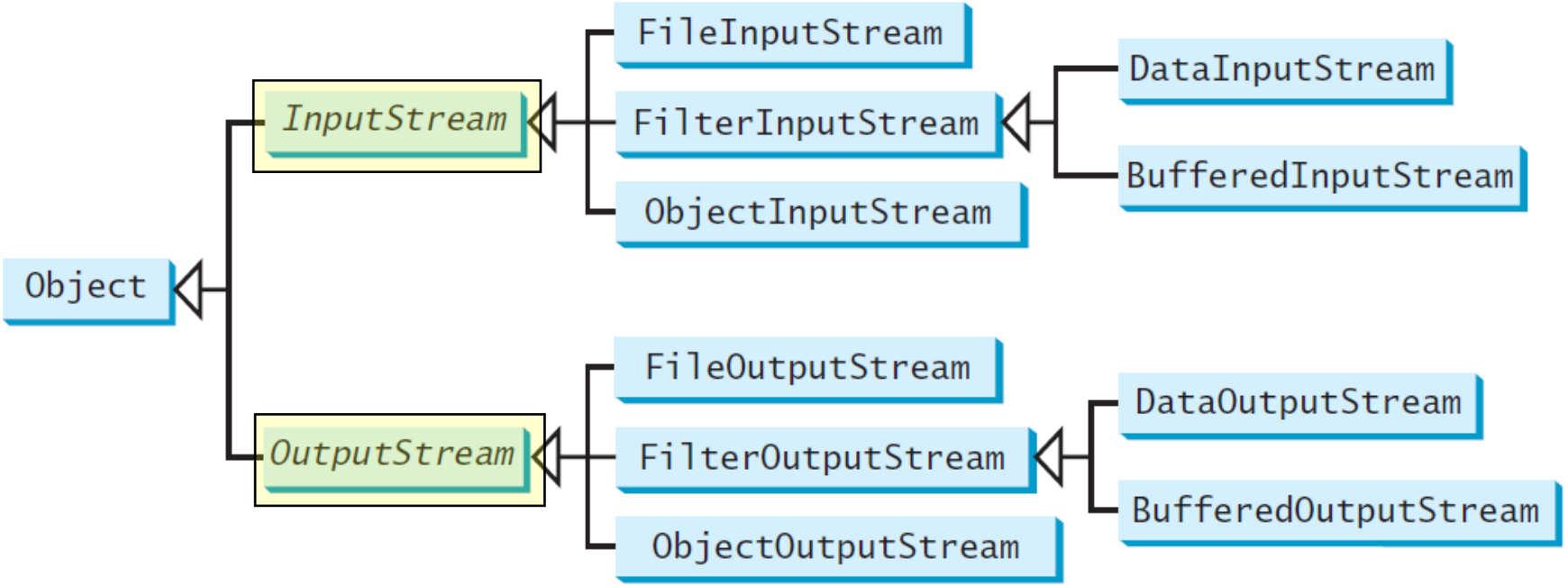
When you write a byte to a file, the original byte is copied into the file. When you read a byte from a file, the exact byte in the file is returned.

Binary I/O classes

- The abstract `InputStream` is the root class for reading binary data
- The abstract `OutputStream` is the root class for writing binary data



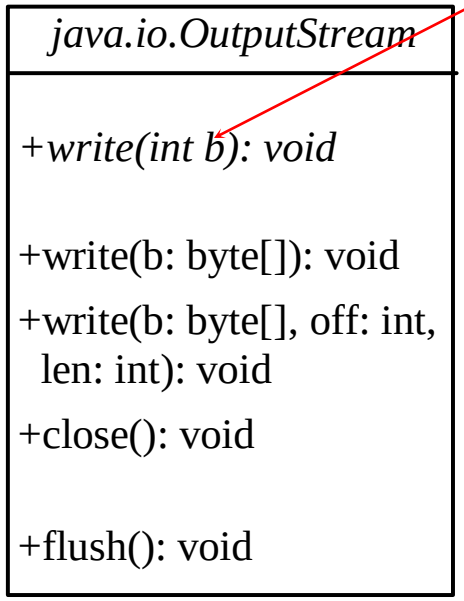
The InputStream class

java.io.InputStream	
+read(): int	Reads the next byte of data from the input stream. The value byte is returned as an int value in the range 0 to 255. If no byte is available because the end of the stream has been reached, the value –1 is returned.
+read(b: byte[]): int	Reads up to b.length bytes into array b from the input stream and returns the actual number of bytes read. Returns -1 at the end of the stream.
+read(b: byte[], off: int, len: int): int	Reads bytes from the input stream and stores into b[off], b[off+1], …, b[off+len-1]. The actual number of bytes read is returned. Returns -1 at the end of the stream.
+available(): int	Returns the number of bytes that can be read from the input stream.
+close(): void	Closes this input stream and releases any system resources associated with the stream.
+skip(n: long): long	Skips over and discards n bytes of data from this input stream. The actual number of bytes skipped is returned.
+markSupported(): boolean	Tests if this input stream supports the mark and reset methods.
+mark(readlimit: int): void	Marks the current position in this input stream.
+reset(): void	Repositions this stream to the position at the time the mark method was last called on this input stream.

The value returned is a byte as an int type

The `OutputStream` class

The value is a byte as an int type



Writes the specified byte to this output stream. The parameter b is an int value. (byte)b is written to the output stream.

Writes all the bytes in array b to the output stream.

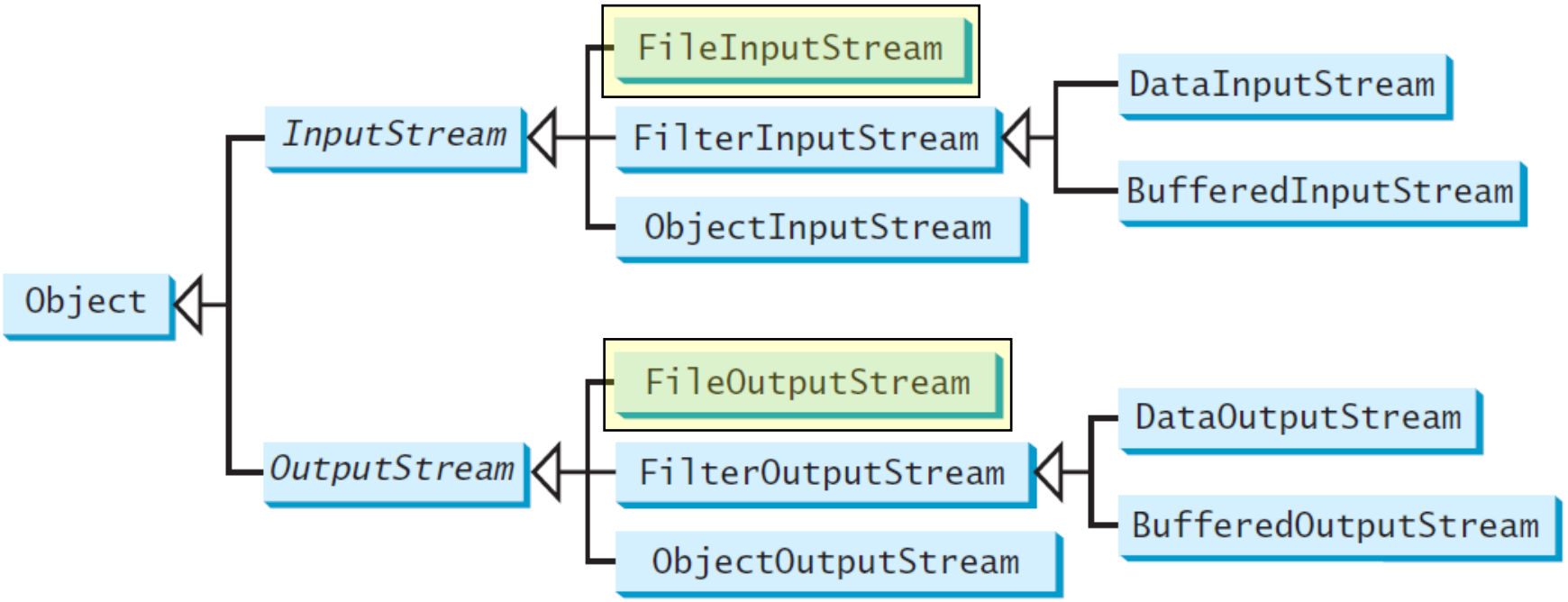
Writes b[off], b[off+1], …, b[off+len-1] into the output stream.

Closes this output stream and releases any system resources associated with the stream.

Flushes this output stream and forces any buffered output bytes to be written out.

Binary file I/O classes

- `FileInputStream`/`FileOutputStream` are for reading/writing bytes from/to files
- All the methods in `FileInputStream` and `FileOutputStream` are inherited from their superclasses



The `FileInputStream` class

- To construct a `FileInputStream` object, use the following constructors

```
public FileInputStream(String filename)
public FileInputStream(File file)
```

- A `java.io.FileNotFoundException` will occur if you attempt to create a `FileInputStream` with a nonexistent file

The `FileOutputStream` class

- To construct a `FileOutputStream` object, use the following constructors

```
public FileOutputStream(String filename)
public FileOutputStream(File file)
public FileOutputStream(String filename, boolean append)
public FileOutputStream(File file, boolean append)
```

- If the file does not exist, a new file will be created
- If the file already exists, the first two constructors will **delete** the current contents in the file
- To retain the current content and **append** new data into the file, use the last two constructors by passing `true` to the append parameter

Binary file I/O using `FileInputStream` and `FileOutputStream`

```
public class TestFileStream {
  public static void main(String[] args) throws IOException {
    try (
      // Create an output stream to the file
      FileOutputStream output = new FileOutputStream("temp.dat");
    ) {
      // Output values to the file
      for (int i = 1; i <= 10; i++)
        output.write(i);
    }

    try (
      // Create an input stream for the file
      FileInputStream input = new FileInputStream("temp.dat");
    ) {
      // Read values from the file
      int value;
      while ((value = input.read()) != -1)
        System.out.print(value + " ");
    }
  }
}
```

Use try-with-resources syntax because classes implement `AutoClosable` interface

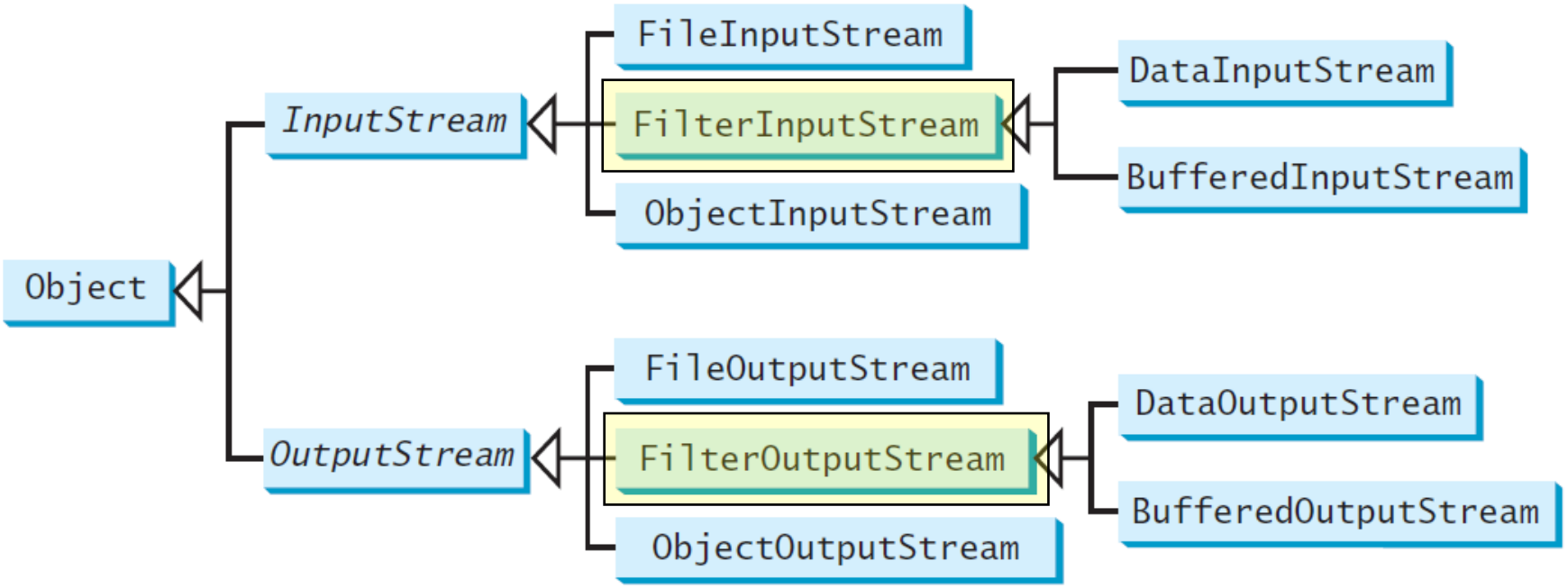
Check for end of file

Filter streams

- `FileInputStream` provides a `read` method that can only be used for reading bytes
  - If you want to read integers, doubles, or strings, you need a filter class to wrap the byte input stream
- *Filter streams* are streams that filter bytes for some purpose
  - Using a filter class enables you to read integers, doubles, and strings instead of bytes and characters

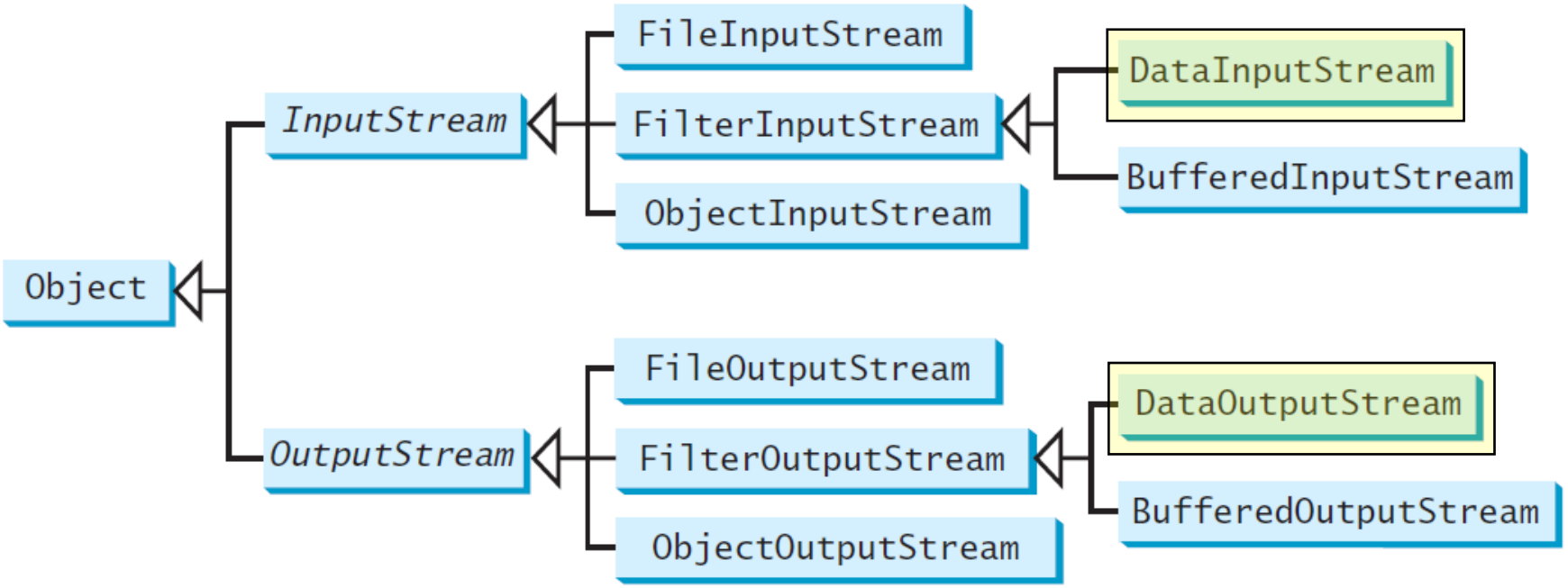
Binary filter I/O classes

- `FilterInputStream` and `FilterOutputStream` are the base classes for filtering data



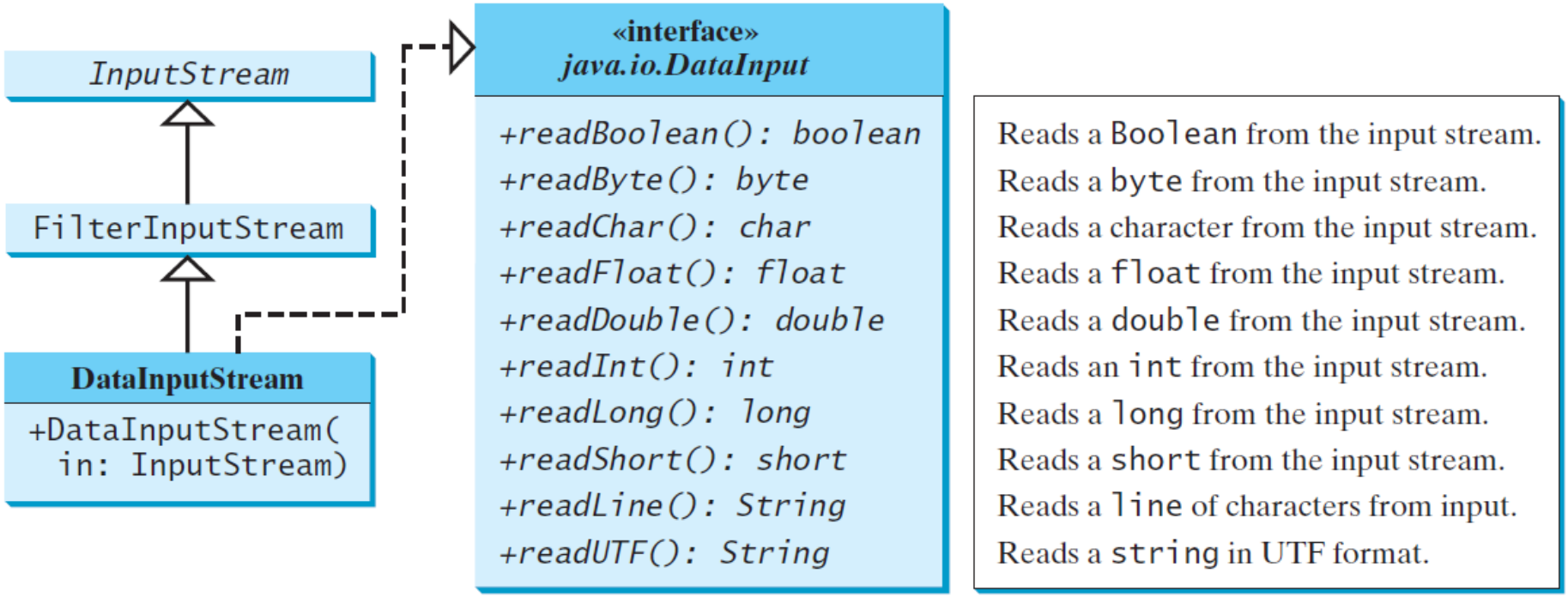
Binary filter I/O classes

- When you need to process primitive numeric types, use `DataInputStream` and `DataOutputStream` to filter bytes



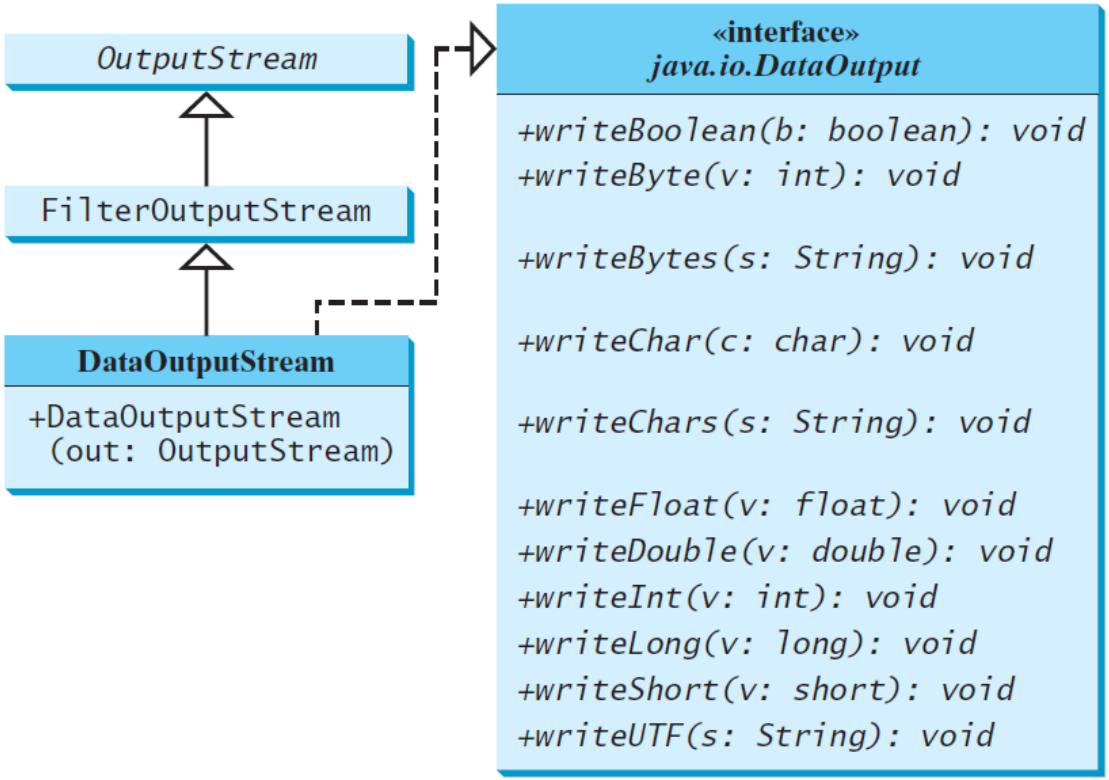
The `DataInputStream` class

- `DataInputStream` reads bytes from the stream and converts them into appropriate primitive type values or strings
- `DataInputStream` extends `FilterInputStream` and implements the `DataInput` interface



The DataOutputStream class

- DataOutputStream converts primitive type values or strings into bytes and output the bytes to the stream
- DataOutputStream extends FilterOutputStream and implements the DataOutput interface



Writes a Boolean to the output stream.	
Writes the eight low-order bits of the argument v to the output stream.	
Writes the lower byte of the characters in a string to the output stream.	
Writes a character (composed of 2 bytes) to the output stream.	
Writes every character in the string s to the output stream, in order, 2 bytes per character.	
Writes a `float` value to the output stream.	
Writes a `double` value to the output stream.	
Writes an `int` value to the output stream.	
Writes a `long` value to the output stream.	
Writes a `short` value to the output stream.	
Writes s string in UTF format.	

Characters and strings in binary I/O

- Remember, a Unicode character consists of two bytes
  - The `writeChar(char c)` method writes the Unicode of character `c` to the output
  - The `writeChars(String s)` method writes the Unicode for each character in the string `s` to the output
- Remember, an ASCII character consists of one byte, which is stored in the **lower byte** of a Unicode character
  - The `writeByte(int v)` method writes the **lowest byte** of integer `v` to the output (i.e., **the higher three bytes of the integer are discarded**)
  - The `writeBytes(String s)` method writes the **lower byte** of the Unicode of the characters in the string `s` to the output (i.e., **the higher byte of the Unicode of the characters are discarded**)

Characters and strings in binary I/O

- Unicode Transformation Format (UTF)
  - The `writeUTF(String s)` method writes the string `s` in UTF
    - UTF is coding scheme for efficiently compressing a string of Unicode characters

Binary file I/O using DataInputStream and DataOutputStream

```
public class TestDataStream {
  public static void main(String[] args) throws IOException {
    try ( // Create an output stream for file temp.dat
      DataOutputStream output =
        new DataOutputStream(new FileOutputStream("temp.dat"));
    ) {
      // Write student test scores to the file
      output.writeUTF("John");
      output.writeDouble(85.5);
      output.writeUTF("Jim");
      output.writeDouble(185.5);
      output.writeUTF("George");
      output.writeDouble(105.25);
    }

    try ( // Create an input stream for file temp.dat
      DataInputStream input =
        new DataInputStream(new FileInputStream("temp.dat"));
    ) {
      // Read student test scores from the file
      System.out.println(input.readUTF() + " " + input.readDouble());
      System.out.println(input.readUTF() + " " + input.readDouble());
      System.out.println(input.readUTF() + " " + input.readDouble());
    }
  }
}
```

You must read the data in the **same order and same format** in which they are stored

End of file (EOF)

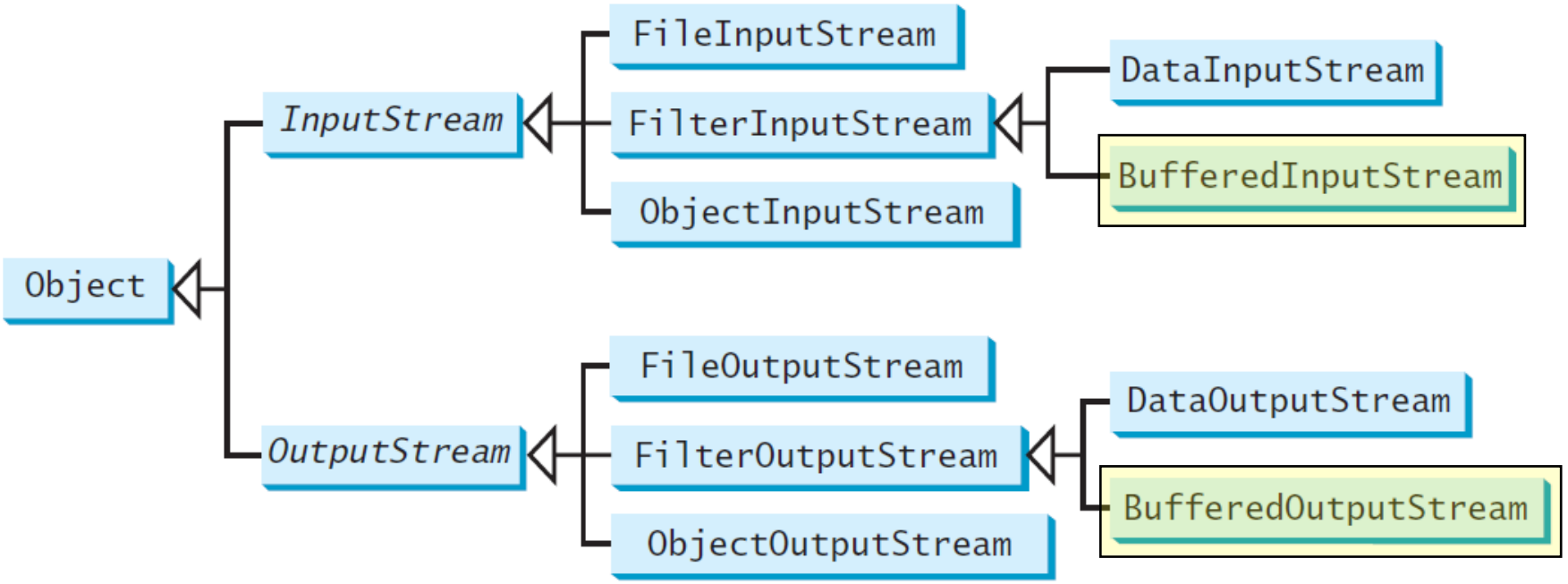
- If you keep reading data at the end of an `InputStream`, then an `EOFException` will occur

```
public class DetectEndOfFile {
  public static void main(String[] args) {
    try {
      try (DataInputStream input =
        new DataInputStream(new FileInputStream("test.dat"))) {
        while (true)
          System.out.println(input.readDouble());
      }
    }
    catch (EOFException ex) {
      System.out.println("All data were read");
    }
    catch (IOException ex) {
      ex.printStackTrace();
    }
  }
}
```

Use `input.available()` to check for EOF (if `input.available() == 0`, then it is EOF)

Binary filter I/O classes

- Use `BufferedInputStream` and `BufferedOutputStream` to speed up input and output by reading ahead and writing later
- All the methods in `BufferedInputStream` and `BufferedOutputStream` are inherited from their superclasses

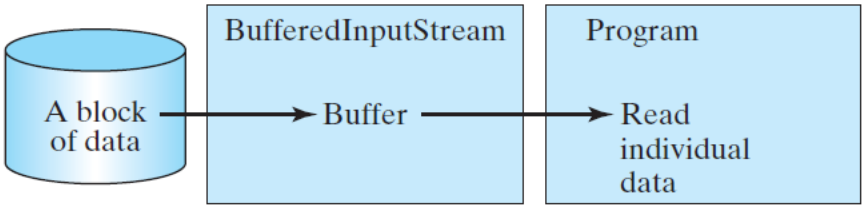


The BufferedInputStream and BufferedOutputStream classes

```
// Create a BufferedInputStream
public BufferedInputStream(InputStream in)
public BufferedInputStream(InputStream in, int bufferSize)

// Create a BufferedOutputStream
public BufferedOutputStream(OutputStream out)
public BufferedOutputStream(OutputStream out, int bufferSize)
```

The default buffer size is 512 bytes



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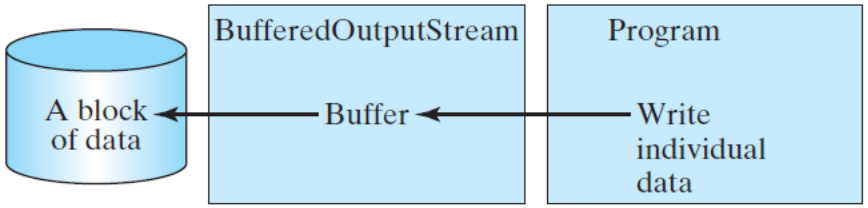

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Example

```
public class Copy {
  public static void main(String[] args) throws IOException {
    // Check command-line parameter usage
    if (args.length != 2) {
      System.out.println(
        "Usage: java Copy sourceFile targetfile");
      System.exit(1);
    }

    // Check if source file exists
    File sourceFile = new File(args[0]);
    if (!sourceFile.exists()) {
       System.out.println("Source file " + args[0] + " does not exist");
       System.exit(2);
    }

    // Check if target file exists
    File targetFile = new File(args[1]);
    if (targetFile.exists()) {
      System.out.println("Target file " + args[1] + " already exists");
      System.exit(3);
    }
    ...
```

Example

```
    ...
    try (
      // Create an input stream
      BufferedInputStream input =
        new BufferedInputStream(new FileInputStream(sourceFile));

      // Create an output stream
      BufferedOutputStream output =
        new BufferedOutputStream(new FileOutputStream(targetFile));
    ) {
      // Continuously read a byte from input and write it to output
      int r;
      int numberOfBytesCopied = 0;
      while ((r = input.read()) != -1) {
        output.write((byte)r);
        numberOfBytesCopied++;
      }

      // Display the file size
      System.out.println(numberOfBytesCopied + " bytes copied");
    }
  }
}
```

Check for end of file

Other binary file I/O

- Objects
  - `ObjectInputStream` and `ObjectOutputStream` can be used to read and write serializable objects
- Random access
  - `RandomAccessFile` allows data to be read from and written to any location (not necessarily sequentially) in the file

CSE 8B topics

- Introduction to Java
- Review fundamentals of programming
- Objects and classes
- Object-oriented thinking
- Inheritance
- Polymorphism
- Abstract classes
- Interfaces
- Class design guidelines
- Exception handling
- Assertions
- Text input/output (I/O)
- Binary I/O
- Recursion
- Event-driven programming

Introduction to Java and review fundamentals of programming

- Introduction to Java and programs
- Elementary programming
- Selections
- Mathematical functions, characters, and strings
- Loops
- Methods
- Single-dimension arrays and multidimensional arrays

Object-oriented programming

- Object-oriented programming (OOP) involves programming using objects
- **This is the focus of CSE 8B**

Objects and classes

- An object represents an entity in the real world that can be distinctly identified
  - For example, a student, a desk, a circle, a button, and even a loan can all be viewed as objects
  - An object has a unique identity, state, and behaviors
- Classes are constructs that define objects of the same type

Object-oriented thinking

- Classes provide more flexibility and modularity for building reusable software
- Class abstraction
  - Separate class implementation from the use of the class
  - The creator of the class provides a description of the class and let the user know how the class can be used
  - The user of the class does not need to know how the class is implemented
  - The detail of implementation is encapsulated and hidden from the user

Inheritance

- Inheritance enables you to define a general class (i.e., a *superclass*) and later extend it to more specialized classes (i.e., *subclasses*)
- A subclass inherits from a superclass
  - For example, both a circle and a rectangle are geometric objects
    - `GeometricObject` is a superclass
    - `Circle` is a subclass of `GeometricObject`
    - `Rectangle` is a subclass of `GeometricObject`
- Models **is-a** relationships
  - For example
    - `Circle` **is-a** `GeometricObject`
    - `Rectangle` **is-a** `GeometricObject`

Polymorphism

- A class defines a type
- A type defined by a subclass is called a *subtype*, and a type defined by its superclass is called a *supertype*
  - For example
    - `Circle` is a subtype of `GeometricObject`, and `GeometricObject` is a supertype for `Circle`
- *Polymorphism* means that a variable of a supertype can refer to a subtype object
  - Greek word meaning “many forms”

Abstract classes

- Inheritance enables you to define a general class (i.e., a *superclass*) and later extend it to more specialized classes (i.e., *subclasses*)
- Sometimes, a superclass is so general it cannot be used to create objects
  - Such a class is called an *abstract class*
- An abstract class cannot be used to create objects
- An **abstract** class can contain abstract methods that are implemented in **concrete** subclasses
- Just like nonabstract classes, models **is-a** relationships
  - For example
    - `Circle` **is-a** `GeometricObject`
    - `Rectangle` **is-a** `GeometricObject`

Abstract classes and interfaces

- A superclass defines common behavior for **related** subclasses
- An *interface* can be used to define common behavior for classes, including **unrelated** classes
- Interfaces and abstract classes are closely related to each other

Interfaces

- An interface is a class-like construct that contains **only** constants and abstract methods
  - In many ways, an interface is similar to an abstract class, but the intent of an interface is to specify common behavior for objects
    - For example, you can specify that the objects are comparable and/or cloneable using appropriate interfaces
- Interfaces model **is-kind-of** relationships
  - For example
    - `Fruit` **is-kind-of** `Edible`

Exception handling

- Exceptions are errors caused by your program and external circumstances
  - These errors can be caught and handled by your program

Assertions

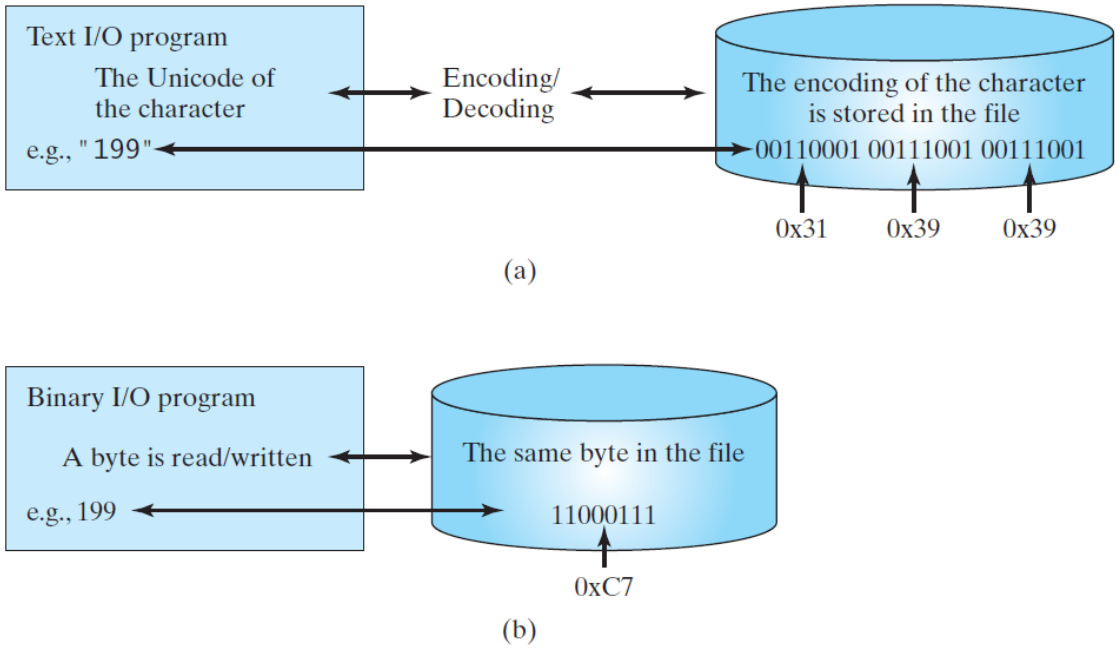
- An assertion is a Java statement that enables you to assert an assumption about your program
- An assertion contains a Boolean expression that should be true during program execution
- Assertions can be used to assure program correctness and avoid logic errors

Text I/O

- In order to perform I/O, you need to create objects using appropriate Java I/O classes
  - The objects contain the methods for reading/writing data from/to a file

Binary I/O

- Binary I/O does not involve encoding or decoding and thus is more efficient than text I/O



Recursion

- Recursion is a technique that leads to elegant solutions to problems that are difficult to program using simple loops
- A recursive method is one that invokes itself directly or indirectly

Event-driven programming

- An event is an object created from an event source
- You can write code to process events such as a button click, mouse movement, and keystrokes

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