03 – Streams & File I/O

David Drohan,
Frank Walsh

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Objectives

- Describe the concept of an I/O stream
- Explain the difference between text and binary files
- Save data, including objects, to a file
- Read data, including objects, from a file

Overview: Outline

- Why Use Files for I/O?
- Text Files and Binary Files
- The Concept of a Stream

Why Use Files for I/O

- Keyboard input, screen output deal with temporary data
  - When program ends, data is gone
- Data in a file remains after program ends
  - Can be used next time program runs
  - Can be used by another program

Text Files and Binary Files

- Files treated as sequence of characters called *text files*
  - Java program source code
  - Can be viewed, edited with text editor
- All other files are called *binary files*
  - Movie, music files
  - Access requires specialized program

Background

- The Java platform includes a number of packages that are concerned with the movement of data into and out of programs. These packages differ in the kinds of abstractions they provide for dealing with I/O (input/output).
- The java.io package defines I/O in terms of *streams*. Streams are ordered sequences of data that have a *source* (input streams) or *destination* (output streams). The I/O classes isolate programmers from the specific details of the underlying operating system, while enabling access to system resources through files and other means.
- The best way to understand the I/O package is to start with the basic interfaces and abstract classes.

Background

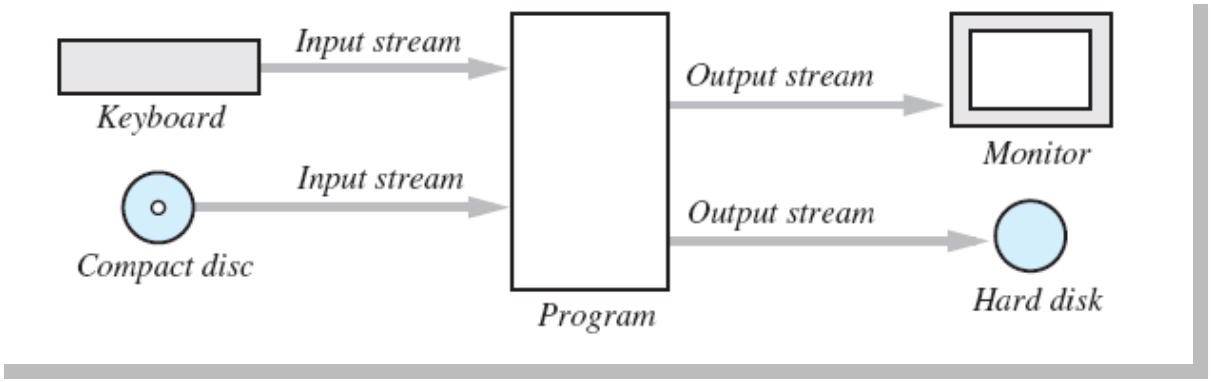
- An *I/O Stream* represents an input source or an output destination. A stream can represent many different kinds of sources and destinations, including disk files, devices, other programs, remote data sources etc.
- Streams support many different kinds of data, including simple bytes, primitive data types, localized characters, and objects. Some streams simply pass on data; others manipulate and transform the data in useful ways.
- No matter how they work internally, all streams present the same simple model to programs that use them: **A stream is a sequence of data.**

The Concept of a Stream

- Use of files in general
  - Store Java classes, programs
  - Store pictures, music, videos
  - Can also use files to store program I/O
- A *stream* is a flow of input or output data
  - Characters
  - Numbers
  - Bytes

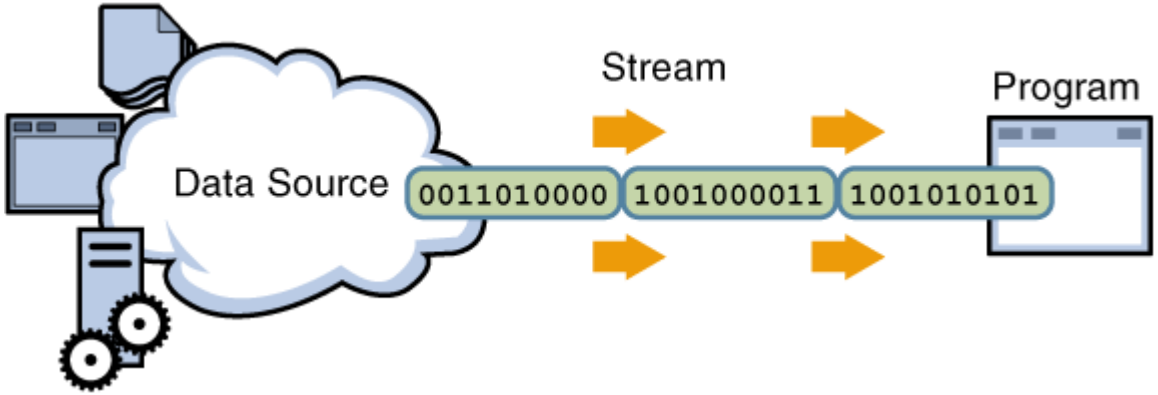
The Concept of a Stream

- Streams are implemented as objects of special stream classes
  - Class **`Scanner / PrintWriter`**
  - Object **`System.out`**

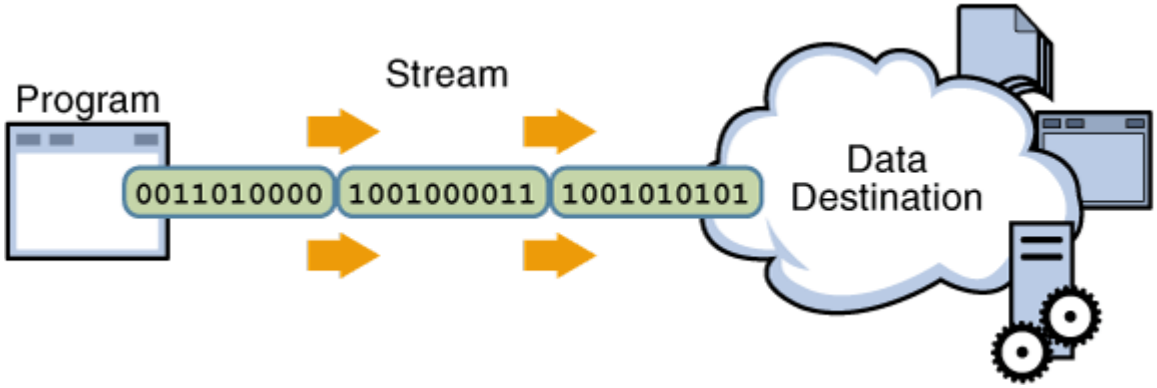


The Concept of a Stream

- A program uses an *input stream* to read data from a source, one item at time:



- A program uses an *output stream* to write data to a destination, one item at time:



Princeton IO classes – Simple Reading data from a File

In: Princeton provided library for reading file data that absracts streaming:

Use In as follows:

```
In fileIn = new In("mydatafile.txt");
double[] data = new double[100];
int i = 0;
while ( ! fileIn.isEmpty() )  data[i++] = fileIn.readDouble()
```

1. This opens a file for reading. Looks for mydatafile.txt in the current working directory where your program is running.
2. Then reads double after double into the array. Stops when there are no more values in the file to be read.

Princeton IO classes – Simple Reading data from a File

Reading in a CSV from file using In.

Ex. Reading a list of people from a file

Data.csv

```
1,Frank, Walsh
2, John,Comber
3, Bob, Hoskins
```

```
String delims = "[|]";
Scanner scanner = new Scanner(new File("./moviedata_small/users5.dat"));
while (scanner.hasNextLine()) {
      String[] data = scanner.nextLine().split(delims);
      Person person = new Person(data[0],data[1],data[2]);
      persons.add(person);
}
scanner.close();
```

- scanner.nextLine() reads in next line of file and returns a String (e.g. "1,Frank, Walsh")
- Split() method of the String class returns an String array by splitting the string using the delimeters specified in his case a comma.

Princeton IO classes – Simple writing data to a File

Use the Out type to write to files:

```
Out out = new Out("myfile.csv");
for (Person person:persons){
    out.println(person);
    }
    out.close();
```

Assumes toString() method of Person returns CSV representation of object

EXAMPLE IN CLASS!!!!

Another way: Creating a Text File

- Class **`PrintWriter`** defines methods needed to create and write to a text file
  - Must import package **`java.io`**
- To open the file
  - Declare *stream variable* for referencing the stream
  - Invoke **`PrintWriter`** constructor, pass file name as argument
  - Requires **`try`** and **`catch`** blocks

Creating a Text File

- File is empty initially
  - May now be written to with method **`println`**
- Data goes initially to memory buffer
  - When buffer full, goes to file
- Closing file empties buffer, disconnects from stream

Creating a Text File

- View sample program

`class TextFileOutputDemo`

```
Enter three lines of text:
A tall tree
in a short forest is like
a big fish in a small pond.
Those lines were written to out.txt
```

Sample screen output

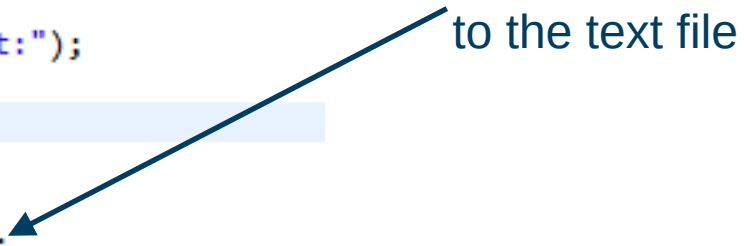
Resulting File

```
1 A tall tree
2 in a short forest is like
3 a big fish in a small pond.
```

You can use a text editor to read this file.

class TextFileOutputDemo

```
public class TextFileOutputDemo
{
    public static void main(String[] args)
    {
        String fileName = "out.txt"; //The name could be read from
                                     //the keyboard.
        PrintWriter outputStream = null;
        try {
            outputStream = new PrintWriter(fileName);
        }
        catch(FileNotFoundException e){
            System.out.println("Error opening the file " + fileName);
            System.exit(0);
        }

        System.out.println("Enter three lines of text:");
        Scanner keyboard = new Scanner(System.in);

        for (int count = 1; count <= 3; count++) {
            String line = keyboard.nextLine( );
            outputStream.println(count + " " + line);
        }
        outputStream.close( );
        System.out.println("Those lines were written to " +
                           fileName);
    }
}
```



Creating a Text File

- When creating a file
  - Inform the user of ongoing I/O events, program should not be "silent"
- A file has two names in the program
  - File name used by the operating system
  - The stream name variable
- Opening, writing to file overwrites pre-existing file in directory

Appending to a Text File

- Opening a file new begins with an empty file
  - If already exists, will be overwritten
- Some situations require appending data to existing file
- Command could be

```
outputStream =
    new PrintWriter(
        new FileOutputstream(fileName, true));
```

- Method `println` would append data at end

Reading from a Text File

- View sample program

  `class TextFileInputDemo`

- Reads text from file, displays on screen
- Note
  - Statement which opens the file
  - Use of `Scanner` object (***not*** `PrintWriter` object)
  - Boolean statement which reads the file and terminates reading loop

Reading from a Text File

```
The file out.txt
contains the following lines:

1 A tall tree
2 in a short forest is like
3 a big fish in a small pond.
```

Sample screen output

class TextFileInputDemo

```
public class TextFileInputDemo
{
    public static void main(String[] args)
    {
        String fileName = "out.txt";
        Scanner inputStream = null;
        System.out.println("The file " + fileName + "\ncontains the following lines:\n");

       try {
           inputStream = new Scanner(new File(fileName));
       }
       catch(FileNotFoundException e) {
           System.out.println("Error opening the file " + fileName);
           System.exit(0);
       }

       while (inputStream.hasNextLine())
       {
           String line = inputStream.nextLine();
           System.out.println(line);
       }
       inputStream.close();
    }
}
```

Reading in from the text file

Working with Binary files

- This Section will cover the following :
  - Introduce a *FileDialog* object which allows the user to specify a *File* (via a GUI)
  - Write ***bytes*** to a *File* and read them back from the *File* using *FileOutputStream* and *FileInputStream*
  - Write values of **primitive data types** to/from a *File* using *DataOutputStream* and *DataInputStream*
  - Write **Objects** to/from a *File* using *ObjectOutputStream* and *ObjectInputStream*
  - Write exception-handling routines using the try-catch block

The Class `File`

- Class provides a way to represent file names in a general way
  - A **`File`** object represents the name of a file
- The object **`(myFile)`** in the statement

```
File myFile = new File ("sample.dat");
```

  is not simply a string
  - It is an object that ***knows*** it is supposed to name a file

The Class `File`

- Suppose we want to read the contents of the file "sample.dat".
  - 1st we must create a File object (from the java.io package)
  - 2nd we must associate the File object with the file itself
- This is achieved as follows :

```
File myFile = new File ("sample.dat");
```

- Note : This assumes the file *sample.dat* is stored in the *current directory.*

Using Path Names

- Files opened in our examples assumed to be in same folder as where program run
- Possible to specify path names
  - Full path name
  - Relative path name
- Be aware of differences of pathname styles in different operating systems

The Class `File`

- The argument to the constructor (“sample.dat”) , specifies the file to access.
- To open a file that is stored in a directory other than the current directory you must also specify a path name.

N.B.

  - `File myFile = new File("C:\\docs", "sample.dat");`

- As a rule, you should also check to see if a File object has correctly been associated with an existing file, by calling its *exists* method.
  - `if(myFile.exists())`
    `{ … }`
- If a vaild association is established, we say *the file is opened,* and we can now proceed with I/O.

Some commonly used `File` methods.

Method	Description
`boolean canRead()`	Returns **`true`** if a file is readable; **`false`** otherwise.
`boolean canWrite()`	Returns **`true`** if a file is writable; **`false`** otherwise.
`boolean exists()`	Returns **`true`** if the name specified as the argument to the **`File`** constructor is a file or directory in the specified path; **`false`** otherwise.
`boolean isFile()`	Returns **`true`** if the name specified as the argument to the **`File`** constructor is a file; **`false`** otherwise.
`boolean isDirectory()`	Returns **`true`** if the name specified as the argument to the **`File`** constructor is a directory; **`false`** otherwise.
`boolean isAbsolute()`	Returns **`true`** if the arguments specified to the **`File`** constructor indicate an absolute path to a file or directory; **`false`** otherwise.
`String getAbsolutePath()`	Returns a **`String`** with the absolute path of the file or directory.
`String getName()`	Returns a **`String`** with the name of the file or directory.
`String getPath()`	Returns a **`String`** with the path of the file or directory.
`String getParent()`	Returns a **`String`** with the parent directory of the file or directory—that is, the directory in which the file or directory can be found.
`long length()`	Returns the length of the file in bytes. If the **`File`** object represents a directory, **`0`** is returned.
`long lastModified()`	Returns a platform-dependent representation of the time at which the file or directory was last modified. The value returned is only useful for comparison with other values returned by this method.
`String[] list()`	Returns an array of **`String`**s representing the contents of a directory.

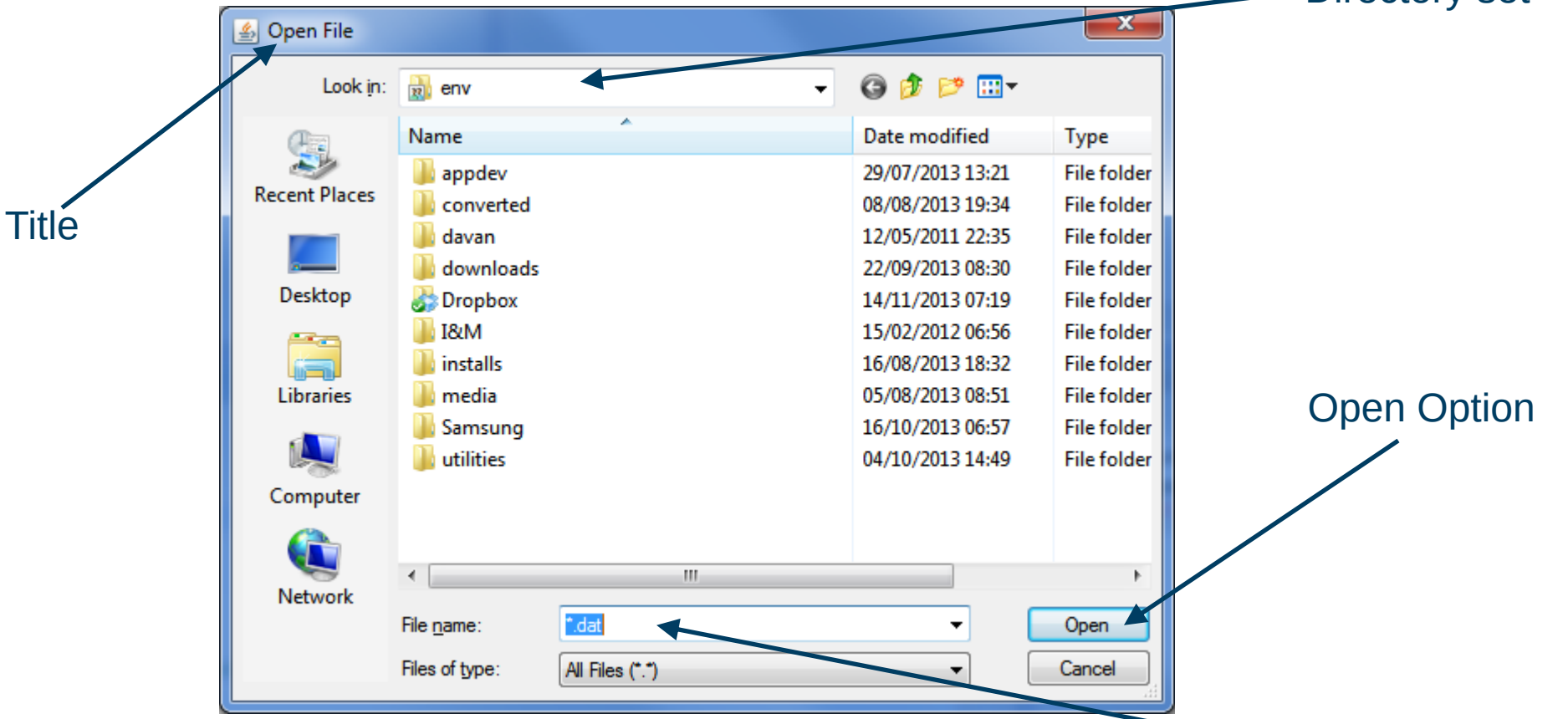
The Class `FileDialog`

- We can let the *user* select a file or a directory, via a GUI, using a *FileDialog* object.
- The object has 2 modes :
  - LOAD : to read data from the specified file
  - SAVE : to write data to the specified/selected file
- The Following code is used to display the Dialog Box below (on the next slide) for Opening a File

```
FileDialog dialog;
Frame frame= new Frame("My Frame"); //required to hold the dialog
dialog = new FileDialog(frame,"Open File",FileDialog.LOAD);
dialog.setDirectory("C:\\env");
dialog.setFile("*.dat");
dialog.setVisible (true);
```

The Class `FileDialog`

- The "Open File" Dialog Box:



- The user can then select a file from the list of files.

The Class `FileDialog`

- To retrieve the name of the file the user has selected, we use the *getFile()* method.

```
String fileName = dialog.getFile();
```

- If the user has selected 'Cancel' the method returns a null string.
- Once we have a filename we can create a new File object.

```
File myFile = new File(fileName); // Current Directory
```

or

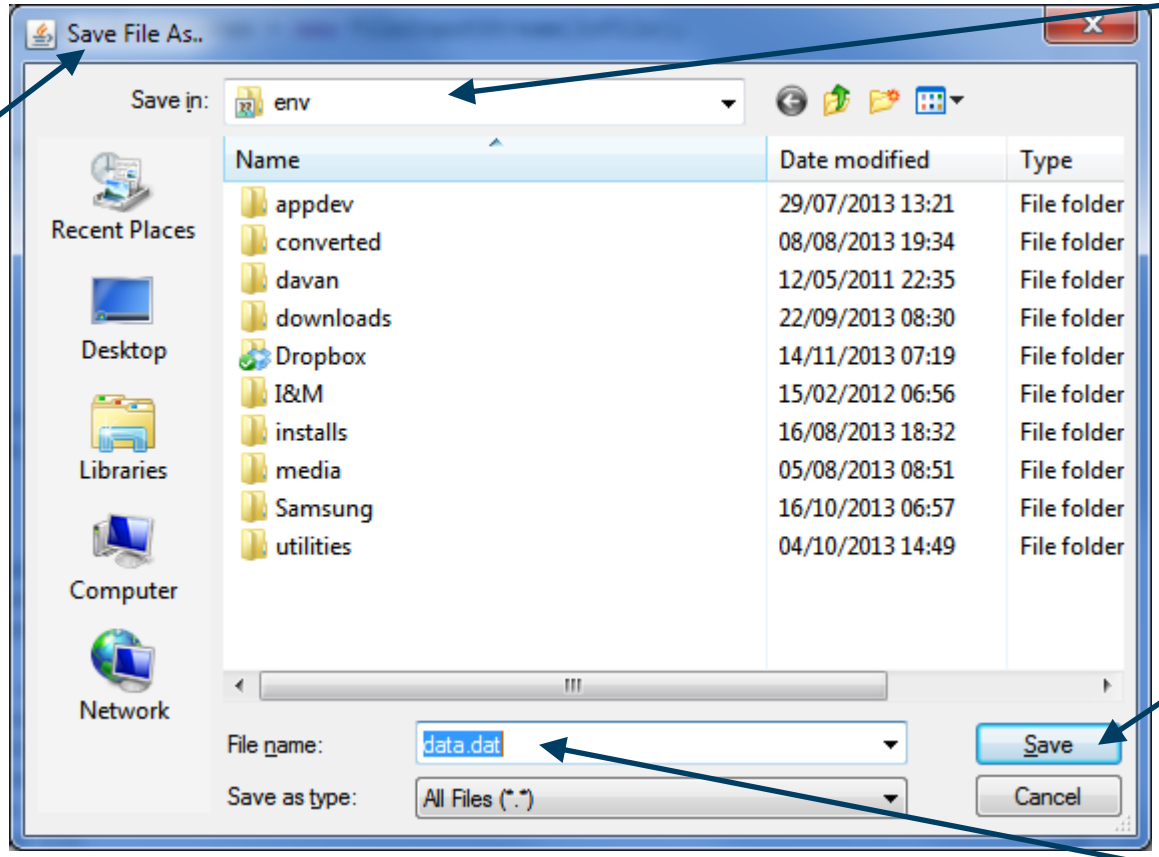
```
File myFile = new File(dialog.getDirectory(), fileName);
```

- To select a file for saving data, we open the *FileDialog* in SAVE mode:

```
dialog.setTitle("File Save As...");
dialog.setMode(FileDialog.SAVE);
dialog.setVisible (true);
```

The Class `FileDialog`

- The "File Save As…" Dialog Box:



Directory set

Title

Save Option

File Name set

- The user can then save the file in the current directory.

Low-Level File I/O (1) – *Byte Streams*

- Programs use *byte streams* to perform input and output of 8-bit bytes. All byte stream classes are descended from *InputStream* and *OutputStream*.
- Once a file is opened (associated properly with a File object), the actual file access can commence.
- In order to read/write from/to a file, we must create one of the Java stream objects and attach it to a file.
- There are many byte stream classes available to us. To demonstrate how byte streams work, we'll focus on the file I/O byte streams, *FileInputStream* and *FileOutputStream*.
  - Other kinds of byte streams are used in much the same way; they differ mainly in the way they are constructed.
- To actually read the data from a file, we attach one of the Java Input Stream objects to the file (ditto for writing)

Low-Level File I/O (2)

- As already mentioned, the two objects that provide low-level (byte) file access are:
  - *FileOutputStream*
  - *FileInputStream*
- With these objects, we can only input/output a sequences of bytes i.e. values of data type byte (we will look at writing other data types and even objects later on)
- To **write** information to a file we can do the following:
  - First, create our File object
    - `File myFile = new File("sample.dat"); // or use FileDialog`
  - Second, associate a new FileOutputStream object to a File
    - `FileOutputStream fos = new FileOutputStream(myFile);`
  - Now we are ready for output

Low-Level File I/O (3)

- Consider the following byte array:

```
byte byteArray[ ] = {10,20,30,40,50,60};
```

- We can write out the whole array at once as follows:

```
fos.write(byteArray);
```

- Or elements Individually:

```
fos.write(byteArray[0]);
```

- Once the values have been written to the memory buffer, we must close the stream, to actually write the data to the file:

```
fos.close();
```

- If a stream is not closed, what are the implications?

Low-Level File I/O (4)

- To **read** data into a program, we reverse the steps in the output routine:
  - First, create our File object (if one doesn't already exist)
    - `File myFile = new File("sample.dat");`
  - Second, associate a new FileInputStream object to a File
    - `FileInputStream fis = new FileInputStream(myFile);`
  - Before we can read in the data, we must first declare and create a byteArray:

```
int filesize = (int) myFile.length()
byte byteArray[ ] = new byte[filesize];
```

  - We use the *length()* method of the File class to determine the size of the file (the number of bytes in the file).
  - We can then read in the data as follows:

```
fis.read(byteArray);
```

Mid-Level File I/O (1) – *Data Streams*

- Data streams support binary I/O of primitive data type values (boolean, char, byte, short, int, long, float, and double) as well as String values.
- All data streams implement either the *DataInput* interface or the *DataOutput* interface.
- This section focuses on the most widely-used implementations of these interfaces, *DataInputStream* and *DataOutputStream*.
- The Following code creates a *DataOutputStream* object:

```
File myFile = new File("Sample1.dat");
FileOutputStream fos = new FileOutputStream(myFile);
DataOutputStream dos = new DataOutputStream(fos);
```

- **N.B. - Since a *DataOutputStream* can only be created as a wrapper for an existing byte stream object, the argument to the *DataOutputStream* constructor is a *FileOutputStream* object. A *DataOutputStream* object does not get connected to a file directly – it's connected via a *FileOutputStream* object (ditto for reading…)**

Mid-Level File I/O (2)

- The *DataOutputStream* object has a number of methods for writing the primitive data types:

```
dos.writeInt(12345689);
dos.writeDouble(12345689.99);
dos.writeChar('A');
dos.writeBoolean(true);
```

- Don't forget to close the stream

```
dos.close();
```

Mid-Level File I/O (3)

- To read the data back from the file, we reverse the operation:

```
File myFile = new File("sample.dat");
FileInputStream fis = new FileInputStream(myFile);
DataInputStream dis = new DataInputStream(fis);
…..
int X = dis.readInt();
Double D = dis.readDouble();
char Y = dis.readChar();
Boolean B = dis.readBoolean();
……
dis.close();
```

- Note : the order of write & read operations must match – **Why?**

File I/O : Exceptions (1)

- Exceptions are usually handled by *catching* a *thrown* exception and providing exception-handling code to process the thrown exception.
- There are two approaches to handling thrown exceptions:
  - Add a *throw* clause to the method header or
  - Use a *try/catch* block in your code
- For simple programs, the first approach may be acceptable, but in general you should use the second approach, in which you write a response code to handle a thrown exception.

File I/O : Exceptions (2)

- Take the following example :

```
class FindSum
   {
    private int result;
    private boolean success;

    public int GetSum( )
                { return result; }

    public boolean isSuccess( )
                { return success; }
```

File I/O : Exceptions (3)

```
void computeSum(String Filename)
     {
     success = true;

       try {
            File myFile = new File(FileName);
            FileInputStream fis = new FileInputStream(myFile);
            DataInputStream dis = new DataInputStream(fis);

            int i = dis.readInt();
            int j = dis.readInt();
            int k = dis.readInt();
            result = i + j + k;
            dis.close();
           } // end of try block

     catch( IOException e )
                  { success = false; }
       } // end of method computeSum
} // end of class FindSum
```

File I/O : Exceptions (4)

```
// In a Program

FindSum obj  = new FindSum( );
obj.computeSum("samplint.dat");

if( obj.isSuccess( ) )
      {
       int total = obj.getSum( );
       // Output total
      }
else
   {
   // Output some File I/O Error Message
   }
```

File I/O : Exceptions (5)

- If an exception is thrown (i.e. an error occurs) during the execution of the *try* block, then the *catch* block is executed and the variable *success* is set to false.
- On a call to the method *isSuccess( )* , a false value is returned and an error message is displayed.
- We can modify the catch block to output an error message itself, as well as setting the success variable:

```
try {…}
catch (IOException e)
  {
  success = false;
  JOptionPane.showMessageDialog(null,e.toString(),"Error
  Message",JOptionPane.ERROR_MESSAGE);
   }
```

File I/O : Exceptions (6)

- There are a number of useful exception classes available, when working with files :
  - You can throw a *FileNotFoundException* if you're trying to open a file that does not exist.
  - You can throw a *EOFException* if you're trying to read beyond the end of a file
- If you want to include statements that will catch any type of exception you can use the following:

```
catch(Exception e)
        {
            …
        }
```

High-Level File I/O - *Object Streams*

- Binary-File I/O with Objects of a Class
- Storing Array Objects in Binary Files

High-Level File I/O

- Consider the need to write/read objects other than **`Strings`**
  - Possible to write the individual instance variable values
  - Then reconstruct the object when file is read
- A better way is provided by Java
  - *Object serialization* – represent an object as a sequence of bytes to be written/read
  - Possible for any class implementing **`Serializable`**

High-Level File I/O – *Case Study*

- We will take a ***Person*** Object as an example to illustrate.
- We assume a Person Object consists of :
  - A Name (String)
  - An Age (int)
  - A Gender (char), ('M' or 'F')

High-Level File I/O – *Case Study*

- Interface **`Serializable`** is an empty interface
  - No need to implement additional methods
  - Tells Java to make the class serializable (class objects convertible to sequence of bytes)
- E.G - **`class Person`**

```
import java.io.*; // we need this for class Serializable

class Person implements Serializable
    {
        // All the declarations / methods
    }
```

High-Level File I/O – *Case Study*

- Once we have a class that is specified as **`Serializable`** we can write objects to a binary file
  - Use method **`writeObject`**
- Read objects with method **`readObject();`**
  - Also required to use typecast of the object

High-Level File I/O – *Case Study*

- To write a Person object to a file, we first create an *ObjectOutputStream* object:

```
File myFile = new File("objects.dat");
FileOutputStream fos = new FileOutputStream(myFile);
ObjectOutputStream oos = new ObjectOutputStream(fos);
```

- To save a Person object, we write :

```
Person p = new Person("Joe Bloggs", 25, 'M');
oos.writeObject(p);
```

- Note : You can save different types of objects to the same file using the *writeObject( )* method.

High-Level File I/O – *Case Study*

- To read a Person object from a file, we first create an *ObjectInputStream* object:

```
File myFile = new File("objects.dat");
FileInputStream fis = new FileInputStream(myFile);
ObjectInputStream ois = new ObjectInputStream(fis);
```

- Then, to read a single Person object from the file, we write :

```
Person p = (Person) OIStream.readObject();
```

- **Note : If you save different types of objects to the same file using the *writeObject( )* method you must ensure that the objects are read back in the correct order, using *readObject( )***

Array Objects in Binary Files

- Since an array is an object itself, it is possible to use **`writeObject`** with an entire array
  - Similarly use **`readObject`** to read entire array
- E.G. - **`class PersonIODemo`** (later slides)

High-Level File I/O – *Case Study*

- Consider the following array of Person objects where N represents some integer value.

```
Person group[] = new Person[N];
```

- Assuming that all N Person objects are in the Array, we can store them to a file a follows:

```
//Save the size of the array first
oos.writeInt(group.length);

 //Save Person Objects next
     for(int i = 0; i< group.length; i++)
                 oos.writeObject(group[i]);
```

- We store the size of the array first, so we know how many Person objects to read back.

High-Level File I/O – *Case Study*

```
int N = OIStream.readInt();
 for(int i = 0; i< N ; i++)
       group[i] = (Person) ois.readObject();
```

- However, since an array itself is an object, we can actually store the whole array at once :

```
oos.writeObject(Group);
```

- And read the whole array back at once :

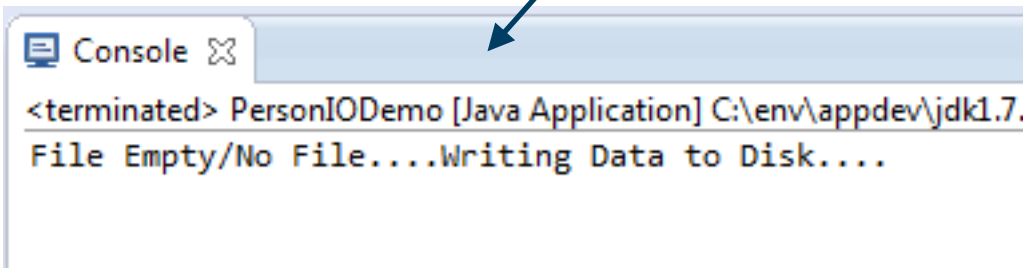
```
group = (Person[])ois.readObject();
```

- Note the type casting of *an array* of Person objects

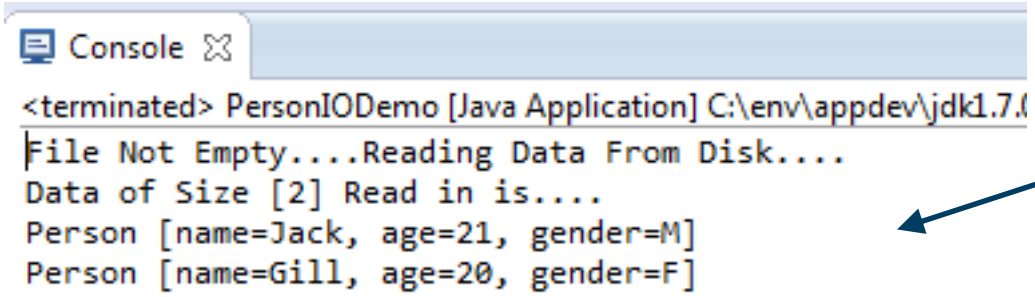
Case Study : PersonIODemo

```
public class PersonIODemo {

    File myFile = new File("objects.dat");
    ObjectOutputStream oos;
    ObjectInputStream ois;
    int size = 0;
    Person[] group = new Person[10];

    public static void main(String[] args)
    {
        new PersonIODemo();
    }
```

Output on 1st Run



Output on 2nd Run



Case Study : PersonIODemo

```
public PersonIODemo()
{
    group[0] = new Person("Jack", 21, 'M');
    group[1] = new Person("Gill",20,'F');
    size = 2;

    try {
    if(myFile.exists())
    {
        System.out.println("File Not Empty....Reading Data From Disk....");
        group = readIn();
        System.out.println("Data of Size [" + size + "] Read in is....");
        for(int i = 0; i < size; i++)
                System.out.println(group[i]);
    }
    else {
        System.out.println("File Empty/No File....Writing Data to Disk....");
        writeOut(group);
        }
    }
    catch (IOException | ClassNotFoundException e)
    {
        e.printStackTrace();
    }

}
```

Case Study : PersonIODemo

```
public void writeOut(Person[] p) throws FileNotFoundException, IOException
{
    oos = new ObjectOutputStream(new FileOutputStream(myFile));
    oos.writeInt(size);
    oos.writeObject(p);
    oos.close();
}

public Person[] readIn() throws FileNotFoundException, IOException, ClassNotFoundException
{
    Person[] temp = null;
        ois = new ObjectInputStream(new FileInputStream(myFile));
        size = ois.readInt();
        temp = (Person[]) ois.readObject();
        ois.close();
    return temp;
}
```

Summary

- Files with characters are text files
  - Other files are binary files
- Programs can use **`PrintWriter`** and **`Scanner`** for I/O
- Always check for end of file
- File name can be literal string or variable of type **`String`**
- Class **`File`** gives additional capabilities to deal with file names

Summary

- Use **`ObjectOutputStream`** and **`ObjectInputStream`** classes enable writing to, reading from binary files
- Use **`writeObject`** to write class objects to binary file
- Use **`readObject`** with type cast to read objects from binary file
- Classes for binary I/O must be **`Serializable`**

Questions?