Object Oriented Programming and Design in Java

Session 22

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Announcements

- Homework 5 due last day of class: Mon. May 3rd
- Mon. May 3rd: Final review
- Mon. May 10th, Final exam. 9 AM - noon
  - closed-book/notes, focus on post-midterm material, but material is inherently cumulative

Review

- Threadsafe wrappers for Collections
- Leftover Design Patterns
  - ADAPTER
  - COMMAND
  - FACTORY METHOD
  - PROXY
  - SINGLETON
  - VISITOR

Today's Plan

- VISITOR pattern
- Networking
- Socket and ServerSocket classes
- Simple text-chat example program

Programming Patterns

MVC

VISITOR

COMPOSITE

PROXY

DECORATOR

ADAPTER

SINGLETON

COMMAND

STRATEGY

FACTORY-METHOD

TEMPLATE-METHOD

Pattern: Visitor

- You're building a hierarchy of classes, and you want to allow new functionality
- but don't want to have clients modify code
- STRATEGY is inadequate if new functionality depends on concrete types
- e.g., file system: DirectoryNode and FileNode
  - want to allow client to add operations, e.g., printing operation, disk-space computation

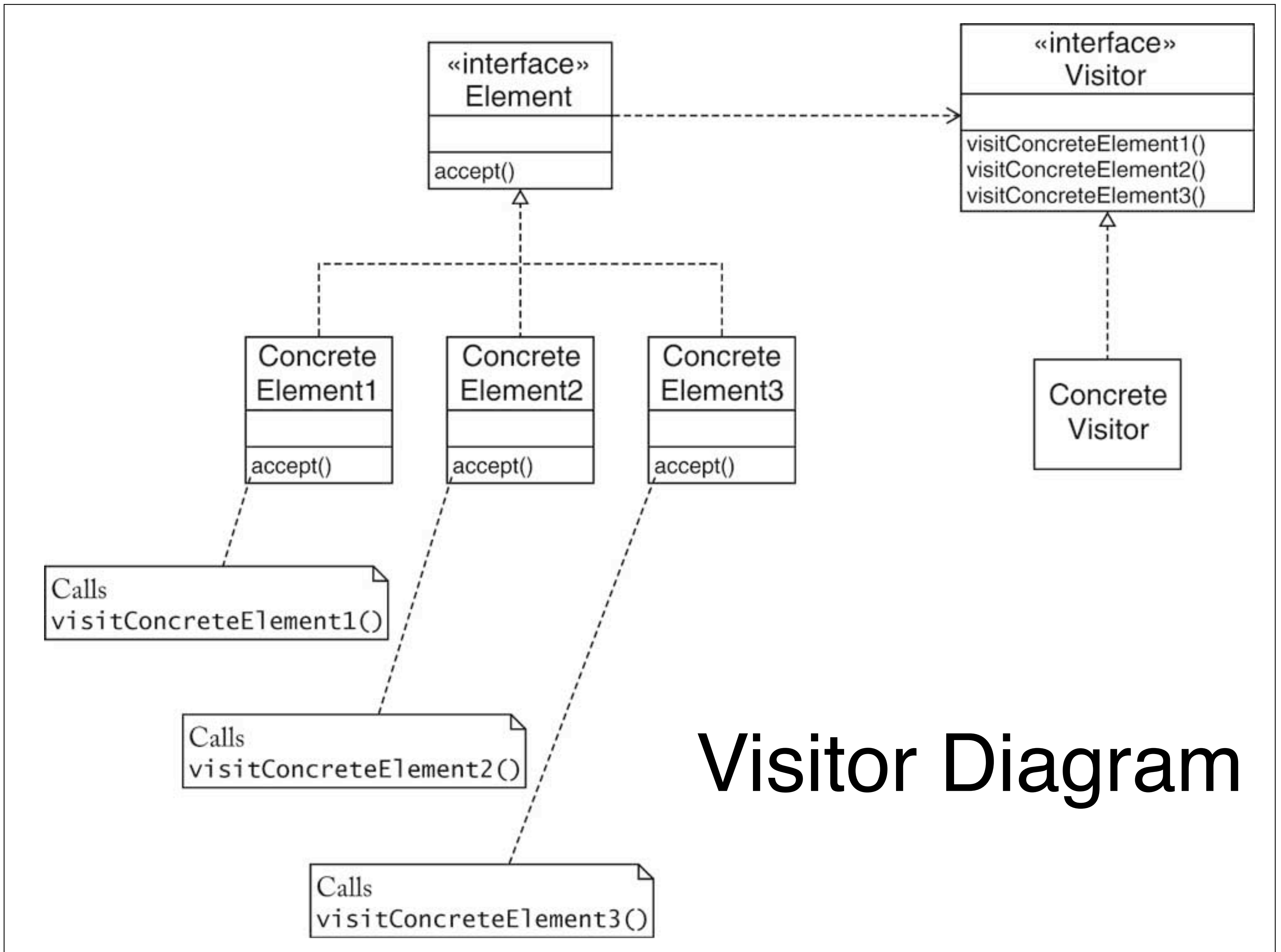
VISITOR

Context

- An object structure contains element classes of multiple types, and you want to carry out operations that depend on the object types
- The set of operations should be extensible over time
- The set of element classes is fixed

Solution

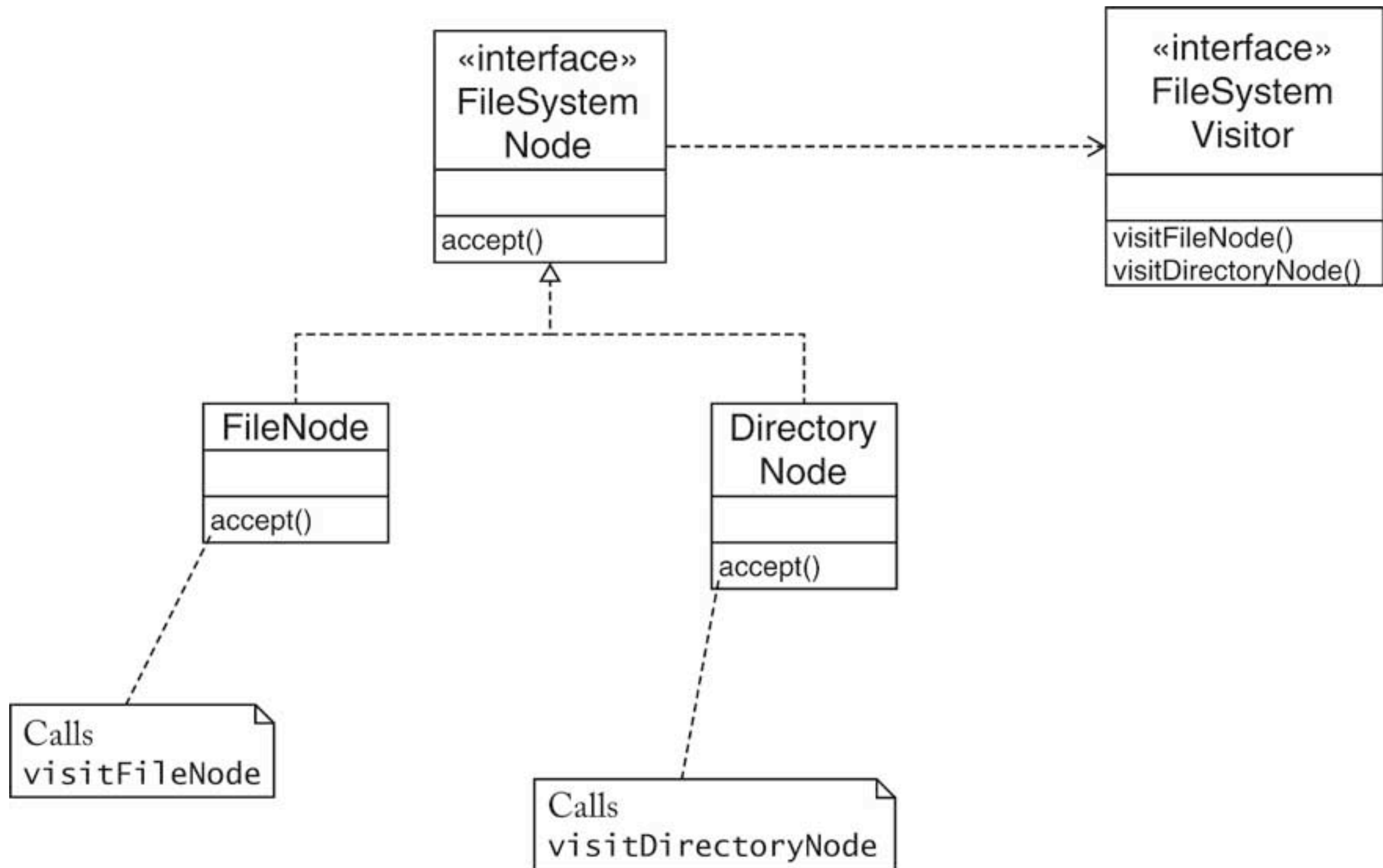
- Define a *visitor* interface that has methods for visiting elements of each of the given types
- Each element class defines an **accept** method that invokes the matching element visitation method on the visitor parameter
- To implement an operation, define a class that implements the visitor interface type and supplies the operation's action for each element type


«interface»
Element
accept()
«interface»
Visitor
visitConcreteElement1()
visitConcreteElement2()
visitConcreteElement3()
Concrete
Element1
accept()
Concrete
Element2
accept()
Concrete
Element3
accept()
Concrete
Visitor
Calls
visitConcreteElement1()
Calls
visitConcreteElement2()
Calls
visitConcreteElement3()
Visitor Diagram

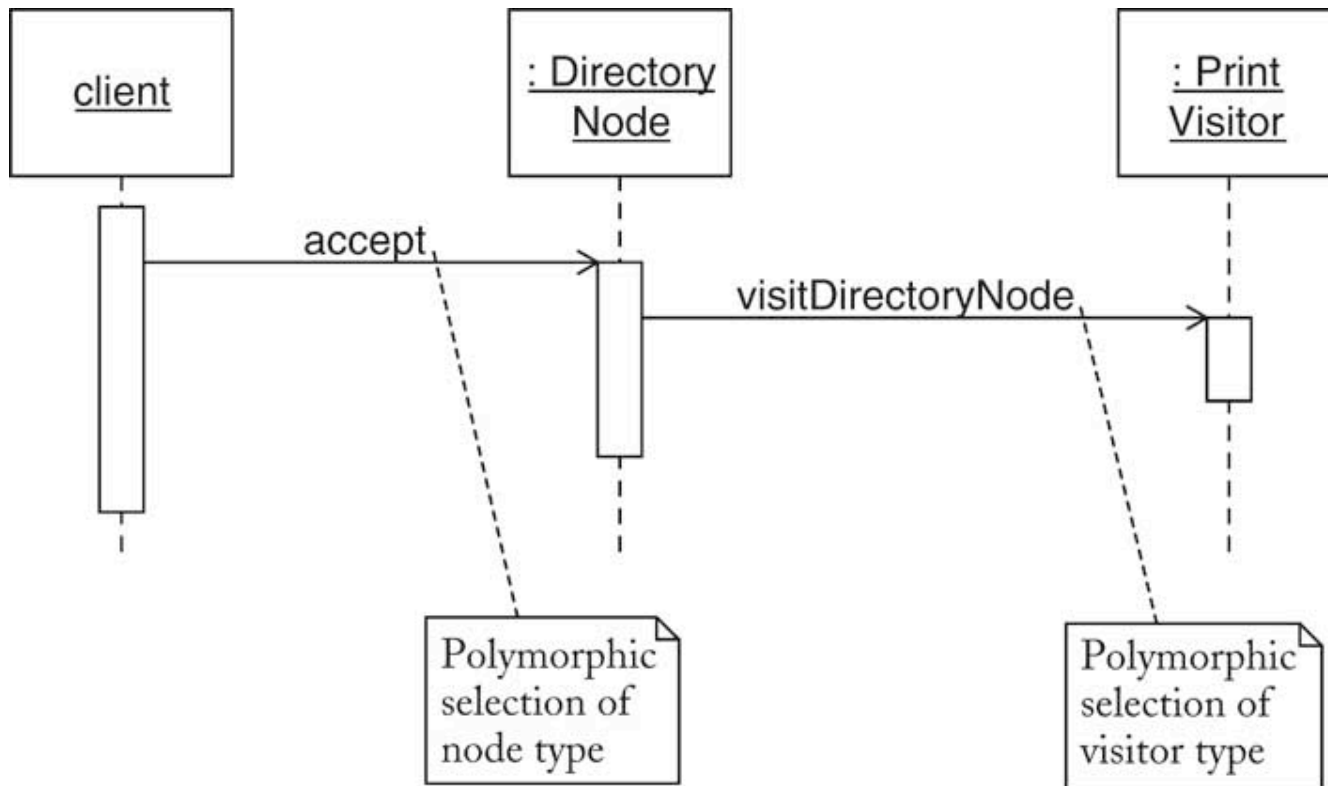
Double Dispatch

- This pattern uses polymorphism twice to make code very general
  - 1st, element.accept() calls Visitor method based on type of element
  - 2nd, the Visitor method performs operation based on type of Visitor
- Both actions called through interfaces
- Concrete classes need not be known at runtime

Example Visitor



Double Dispatch in FileSystemNode



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Networking

- Modern computing is done over the Internet
- This includes, but is far more general than the World Wide Web and websites transferred over http
- Data over the internet is divided into two types of raw information: application data and network protocol data
- Network protocol data tells the routers, switches and computers where the data came from, where it's headed, how to check for errors, lost data, etc.

The Internet Protocol (IP)

- Computers on the Internet have IP addresses, which are four byte numbers, like 128.59.48.24 (www.columbia.edu)
- Domain Name Servers (DNS) map these IP addresses to easier-to-remember names
- IP transmits data in small chunks known as *packets*, which contain validation information so the receiving computer can tell if the data was corrupted
- If data is corrupted or lost, IP doesn't say what to do about it, which is why many Internet communications also use *Transmission Control Protocol* (TCP)

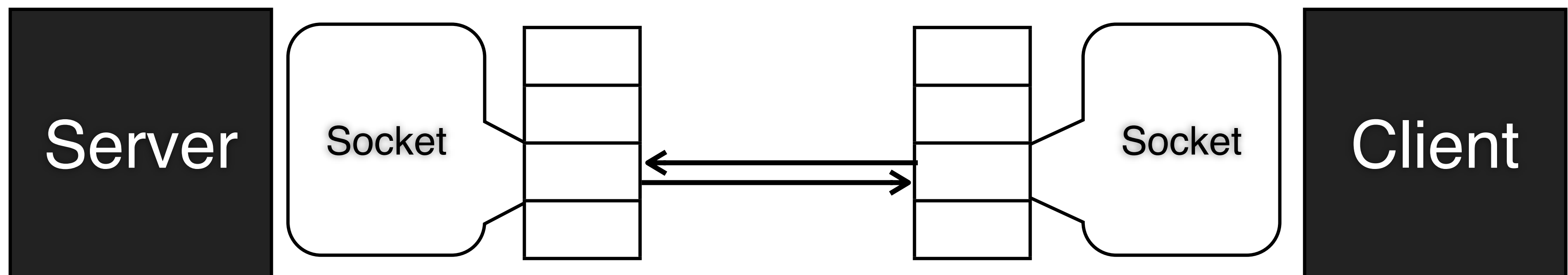
TCP/IP

- Transmission Control Protocol retries packet transmission if there is a failure
- Programs can abstract away transmission details using TCP/IP
- The protocol is responsible for reliable transmission (or elegantly notifies of an error)
- A lot of details, but the important pieces of a TCP/IP packet are:
  - Sender's IP address and *port*
  - Receiver's IP address and *port*

Ports

- Since most computers only have one or two network connections, must distinguish between messages from different programs
- TCP/IP packets have 16-bit number (0, 65535) called a *port,* indicates what program should handle it
- 80 is the Web, 22 is ssh, 993 is IMAP/SSL
- Ports 0-1023 restricted, but we can use the larger numbers for our programs

Sockets



- On each side of a TCP/IP connection, there is a *socket*
- Java lets us abstract away the details and work with the sockets
- One end is a *server* and the other is a *client*
- Each socket has an InputStream and an OutputStream

Socket API

- Common constructor:
  `new Socket(String host, int port)`
- `InputStream getInputStream()`
- `OutputStream getOutputStream()`
- `void close()`
- IOExceptions everywhere; lots of try/catch blocks in Socket code
- But how do we set up the host? ServerSocket

ServerSocket API

- Constructor:
  `new ServerSocket(int port)`
- `Socket accept() // Listens for a connection to be made and accepts it`
- `close();`
- Get Sockets using accept() and perform logic with them using their InputStream and OutputStream
- Usually, wrap with `new BufferedReader(socket.getInputStream())`
  - and `new PrintWriter(socket.getOutputStream())`

Simple Two-Way Text Chatting

- TextServer - establishes connection, responsible for exception handling
- TextClient - establishes connection, responsible for exception handling
- TwoWayChatServer - reads input from console and sends it to client, prints messages from client
- TwoWayChatClient - reads input from console and sends it to server, prints messages from server

TextServer.java

```
public class TextServer {
   /**
    *  Constructor takes a port number and
    *  opens a single-connection server on that port
    * @param port port to listen on
    */
   public TextServer(int port)
   {
      try {
         server = new ServerSocket(port);

         clientSocket = server.accept();
         out = new PrintWriter(
              clientSocket.getOutputStream(), true);
         in = new BufferedReader(
              new InputStreamReader(clientSocket.getInputStream()));

      } catch (IOException e) {
         System.err.println("Error opening server streams");
         System.exit(-1);
      }
   }

   /**
```

```java
/**
 * Reads a line sent by the client
 * @return the line sent by client
 */
public String readLine()
{
   try {
      return in.readLine();
   } catch (IOException e) {
      e.printStackTrace();
      return null;
   }
}

/**
 * Writes a line to the client
 * @param line String to send to client
 */
public void writeLine(String line) { out.println(line); }

/**
 * Accessor for BufferedReader
 * @return BufferedReader representing input from client
 */
```

```java
    /**
     * Closes the connection to client
     */
    public void closeClient() {
        try {
            clientSocket.close();
        } catch (IOException e) { e.printStackTrace(); }
    }

    /**
     * Closes the server
     */
    public void closeServer() {
        try {
            server.close();
        } catch (IOException e) { e.printStackTrace(); }
    }

    private PrintWriter out;
    private BufferedReader in;
    private ServerSocket server;
    private Socket clientSocket;
}
```

TextClient.java Constructor

```
public TextClient(String hostname, int port)
{
   try {
      clientSocket = new Socket(hostname, port);

      out = new PrintWriter(
            clientSocket.getOutputStream(), true);
      in = new BufferedReader(
            new InputStreamReader(clientSocket.getInputStream()));

   } catch (IOException e) {
      System.err.println("Error opening server streams");
      System.exit(-1);
   }
}
```

TwoWayChatServer.java Main Loop

```
TextServer server = new TextServer(port);
server.writeLine("Connected to server");

// start back-and-forth chatting
String line;
while((line = server.readLine()) != null) {
   System.out.println(line);
   try {
      server.writeLine(stdin.readLine());
   } catch (IOException e) {
      e.printStackTrace();
   }
}
```

TwoWayChatClient.java Main Loop

```
TextClient client = new TextClient(hostname, port);

// start back-and-forth chatting
String line;
while ((line = client.readLine()) != null)
{
   System.out.println(line);
   try {
      client.writeLine(stdin.readLine());
   } catch (IOException e) {
      e.printStackTrace();
   }
}

client.close();
```

Multithreading

- These programs work, but the conversation must alternate back and forth between the client and server
- We need multithreading to allow remote messages to be displayed immediately while waiting for System.in input
- ThreadedBufferedReaderPrinter - Runnable: continually prints output from BufferedReader ASAP
- ThreadedChatServer - reads input from console and sends it to client, starts TBRP thread
- ThreadedChatClient - reads input from console and sends it to server, starts TBRP thread

```java
public class ThreadedBufferedReaderPrinter implements Runnable {

   /**
    * Constructor takes the BufferedReader to print
    * @param reader the BufferedReader to print
    */
   public ThreadedBufferedReaderPrinter(BufferedReader reader) {
      this.reader = reader;
   }

   public void run() {
      String line;
      try {
         while (!Thread.interrupted() &&
               (line = reader.readLine()) != null) {
            System.out.println(line);
         }
      } catch (IOException e) {
         e.printStackTrace();
      }
   }

   BufferedReader reader;
}
```

ThreadedBufferedReaderPrinter

ThreadedChatClient Main Loop

```
// hostname and port loaded

TextClient client = new TextClient(hostname, port);

// Start printing thread
Thread t = new Thread(new
     ThreadedBufferedReaderPrinter(client.getReader()));
t.start();

// start chatting
while (client.isConnected()) {
   try {
      client.writeLine(stdin.readLine());
   } catch (IOException e) {
      e.printStackTrace();
   }
}
```

ThreadedChatServer Main Loop

```
// port loaded

TextServer server = new TextServer(port);
server.writeLine("Connected to server");

// Start printing thread
Thread t = new Thread(new
     ThreadedBufferedReaderPrinter(server.getReader()));
t.start();

// start chatting
while (server.isConnected()) {
   try {
      server.writeLine(stdin.readLine());
   } catch (IOException e) {
      e.printStackTrace();
   }
}
```

ThreadedMultiChatServer

- Handle multiple connections with threads
  - while (true)
accept connection
start thread to handle connection
- Multiple clients can connect to the chat server
- Each client managed by a thread, when any client sends a message, bounce to all connected clients
- Store client OutputStreams in a List, all client-handling threads share the list

```java
public class MultiChatHandler implements Runnable {

   public MultiChatHandler(BufferedReader reader,
         List<PrintWriter> outputs, InetAddress addr)
   {
      this.reader = reader;
      this.outputs = outputs;
      name = addr.toString();

      printAll("A new client connected.");
   }

   public void run() {
      while (!Thread.interrupted()) {
         String line = null;
         try {
            line = reader.readLine();
         } catch (IOException e) {
            e.printStackTrace();
         }
         System.out.println(line);
         printAll(line);
      }
   }
```

MultiChatHandler

MultiChatHandler

```java
            try {
                line = reader.readLine();
            } catch (IOException e) {
                e.printStackTrace();
            }
            System.out.println(line);
            printAll(line);
        }
    }

    /**
     * Print something to all connected clients
     * @param line
     */
    private void printAll(String line)
    {
        for (PrintWriter pw : outputs)
            pw.println(name + ": " + line);
    }

    BufferedReader reader;
    List<PrintWriter> outputs;
    String name;
}
```

ThreadedMultiChatServer Main Loop

```
List<PrintWriter> allOut = new ArrayList<PrintWriter>();

while(true) {
   try {
      Socket client = server.accept();
      allOut.add(new PrintWriter(client.getOutputStream(), true));
      BufferedReader in = new BufferedReader(
            new InputStreamReader(client.getInputStream()));

      Thread t = new Thread(new
            MultiChatHandler(in, allOut, client.getInetAddress()));
      t.start();
   } catch (IOException e) {
      System.err.println("Error connecting client.");
   }
}
```

Reading

- Horstmann Ch. 10 for Patterns
- http://java.sun.com/docs/books/tutorial/networking/sockets/index.html
- Optional: Ch. 22.1-22.4 in Big Java by Horstmann if you still have it from 1004
- http://www.cs.columbia.edu/~bert/courses/1007/code/networking/