Sockets: lower-level view via Oracle

- **Oracle** here is the Oracle of Bacon, hosted at UVA
  - Uses IMDB to develop database
  - Constructs graph from database, uses graph for queries
  - Server responds to several kinds of queries, all done via a lower-level socket-based protocol

- **What are sockets in this and other network contexts?**
  - Two-way pipe between programs, slightly different for client and server
    - Server accepts client connections, establishes the socket
    - Socket provides input/output streams
  - Bytes go in both directions, protocol needed to exchange information

Oracle.java: sockets in Java

```java
mySocket = new Socket(host, port);
myInput =
    new DataInputStream(mySocket.getInputStream());
myOutput =
    new DataOutputStream(mySocket.getOutputStream());
try{
    myOutput.WriteByte(BYNUMBER);   // protocol driven
    write(actor);                   // write a string
    writeInt(steps);                // distance away
    myOutput.WriteByte(USE_MOVIES); // protocol driven
    myOutput.flush();
}
```

- **What should we see in this client program to understand it?**

All actors N-steps from named actor

- **What is server protocol, what code do you need to see?**
  - Any obvious refactorings that would help and hurt?

```java
int fd = sock_connect(SERVER, PORT);
if (fd == -1) return -1;
wfp = fdopen(fd, "w");
rfp = fdopen(fd, "r");
putc(CMD_BY_NUMBER, wfp);
putstring(argv[1], wfp);
putint(atoi(argv[2]), wfp);
putc(USE_MOVIES, wfp);
fflush(wfp);
while ((res = fgetc(rfp)) == RSP_LINK_ENT) {
    char *s = getstring(rfp);
    puts(s);
    free(s);
}
```

multi-platform, multi-os client/server

- **Architectural issues impact client/server code**
  - Little-endian/Big-endian issues
    - 0xabcd is a 32-bit value, which is MSB? How is this stored?
  - How big is an int? 32-bits, 64 bits, …
  - Other issues

- **Towards raising the level of discussion**
  - Worrying about integer byte order is not fun and it can be frustrating
  - Let’s worry about sending objects back-and-forth, not bytes
  - How does an object on one machine communicate with another object on a different machine
Writing objects: towards COM/Corba/...  
- The Java stream hierarchy is a rich source of options  
  - Object streams, Data streams, Buffered Readers, ...  
  - Often these convert between bytes and characters  
    - What’s the story with Unicode? (e.g. compared to ASCII)  
    - FileInputStream, BufferedReader, ...  
- We can read and write objects over sockets  
  - Advantages compared to lower-level protocols?  
  - Disadvantages?  
- Issues in understanding and implementing  
  - Where do objects “live”, are classes different?  
  - Subclass/Superclass issues  
  - What about connection issues (where, how, knowledge)  

Clients and Servers  
- Server socket exists on some machine, listens to a “port”  
  - A port isn’t a physical concept, it’s an OS concept  
  - The OS manages ports, some services listen at predetermined ports, e.g., mail at port 25  
    - User programs use ports above 1024  
- Server gets a connection and handles the request, but what about other connection requests?  
  - Can’t be too busy processing request, or will miss other attempts at connections  
  - Spin off handler as a separate program/process  
- See EchoServer.java and Client.java as examples  
  - What does client do?  

From controller to threads  
- Threads are lightweight processes (what’s a process?)  
  - Threads are part of a single program, share state of the program (memory, resources, etc.)  
  - Several threads can run “at the same time”  
    - What does this mean?  
  - Every Swing/AWT program has at least two threads  
    - AWT/event thread  
    - Main program thread  
- Coordinating threads is complicated  
  - Deadlock, starvation/fairness  
  - Monitors for lock/single thread access  

Concurrent Programming  
- Typically must have method for ensuring atomic access to objects  
  - If different threads can read and write the same object then there is potential for problems  
  - If an object is read-only, there are no issues in concurrent programming  
    - String is immutable in Java, other classes can have instance variables be defined as final, cannot change (like const)  
- In Java, the keyword synchronized is the locking mechanism used to ensure atomicity  
  - Uses per-object monitor (C.A.R. Hoare), processes wait to get the monitor, it’s re-entrant
Using synchronized methods

- Methods can be synchronized, an object can be the argument of a synchronized block, a class cannot be synchronized
  - Every object has a lock, entering a synchronized method of the object, or using the object in a synchronized block, blocks other threads from using synchronized methods of the object (since the object is locked)
  - If a synchronized method calls another synchronized method on the same object, the lock is maintained (even recursively)
  - Another thread can execute any unsynchronized method of an object O, even if O's lock is held
  - A thread blocks if it tries to execute a synchronized method of an object O if O's lock is held by a different thread

Thread classes in Java

- Classes can extend java.lang.Thread or implement java.lang.Runnable, (note: Thread implements Runnable)
  - A thread's run method is executed when the thread is started
  - Typically the run method is “infinite”
    - Executes until some final/done state is reached
    - The run method must call sleep( ) or yield(); if not the thread is selfish and once running may never stop
  - A runnable object is run by constructing a Thread object from the runnable and starting the thread

- Threads have priorities and groups
  - Higher priority threads execute first
  - Thread groups can be a useful organizational tool