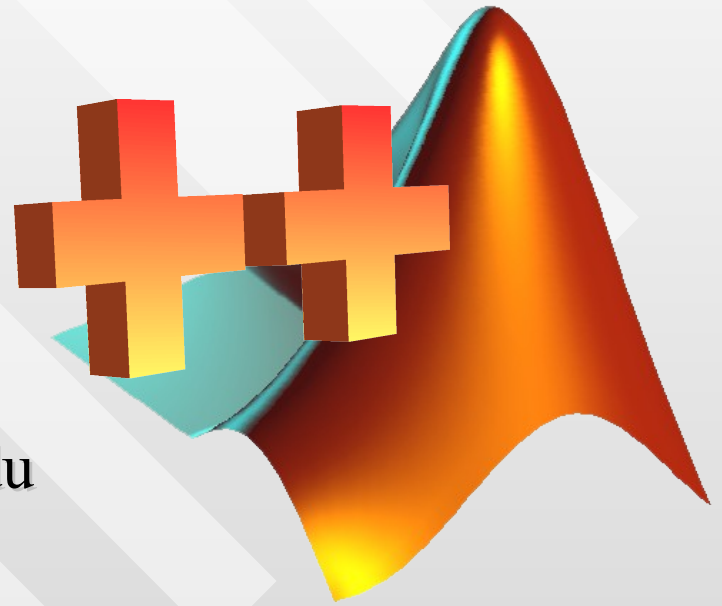


Javalab

IAP 2009

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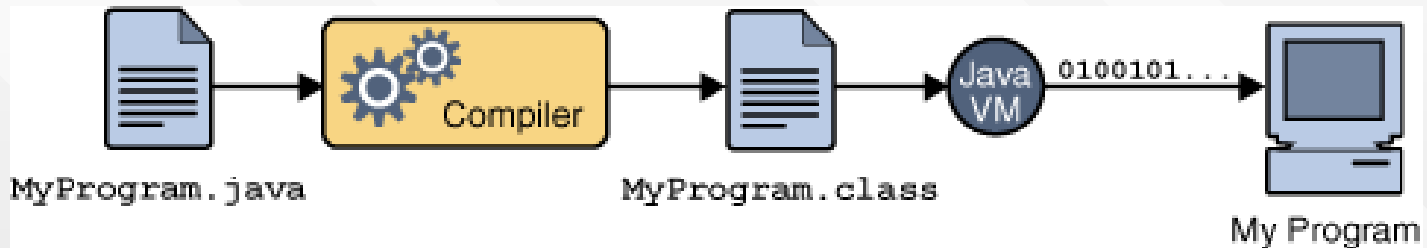
<http://stellar.mit.edu/S/project/advanced-matlab/>

What is Java?

- Compiled, OO language
- High-level, easy to use
- Many prebuilt libraries
- Universal
- Part of Matlab

- <http://java.sun.com/docs/books/tutorial/index.html>

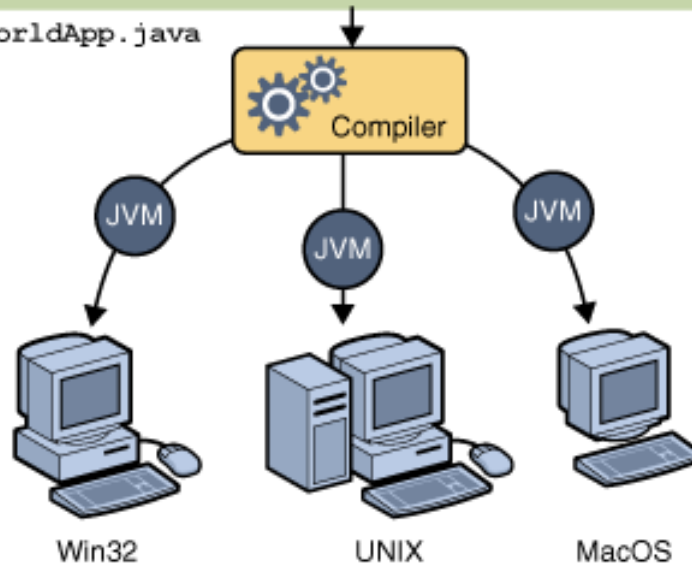
What is Java?



Java Program

```
class HelloWorldApp {  
    public static void main(String[] args) {  
        System.out.println("Hello World!");  
    }  
}
```

HelloWorldApp.java



What is Java?

- Relative speeds
 - C/C++: 1
 - Java: 1/1.5
 - Interpreted M-code: $< 1/100$
 - JIT M-code: $\sim 1/2$?

What is Java?

- **Explicit benefits:**
 - Compiled classes (and everything)
 - JNI, threading, system access etc
 - Web access/beans/etc
 - Universal
 - Compressed/encrypted package deployment
 - Pointers and OOP
 - GUI's

What is Java?

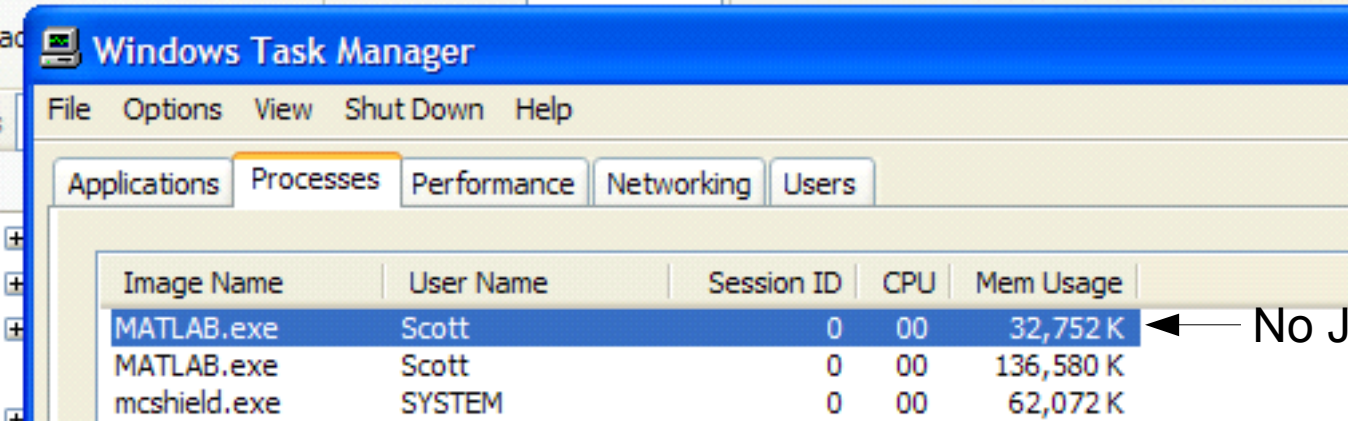
- Terminology
 - Java: Language specification (*cf M-code*)
 - JVM – Java Virtual Machine, runs compiled Java objects (*cf Matlab.exe*)
 - JRE – Java Runtime Environment, is the actual code that creates and controls the JVM, and specifies the running version of Java (*cf Matlab version, environment, path, etc*)

1st thing to know about Java

- Matlab runs with an internal JVM
 - This controls the desktop, figures, and some built-in functions (ie timer)
- You can turn it off:
 - ‘-nojvm’ start flag
 - Right click on shortcut, add to end of ‘Target’
 - Matlab runs in console mode only

1st thing to know about Java

- Resource Management
 - Matlab won't spend time on desktop, UI
 - Always use '-nojvm' or '-nodesktop' for time-critical code



Windows Task Manager

File Options View Shut Down Help

Applications Processes Performance Networking Users

Image Name	User Name	Session ID	CPU	Mem Usage
MATLAB.exe	Scott	0	00	32,752 K
MATLAB.exe	Scott	0	00	136,580 K
mcshIELD.exe	SYSTEM	0	00	62,072 K

← No JVM

1st thing to know about Java

- #1 reason for Matlab crashes prior to r7.2, and 7.6+ (7.4 works much better)
 - JVM heap overflows
 - Lots of red text in console -> JVM error
- This may be because Matlab DOES NOT use the public JRE, but an internal version

1st thing to know about Java

- You can update the JRE
 - Download the appropriate JRE (java.com)
 - Add environment variable “MATLAB_JAVA” which is the path to the JRE
 - <http://www.mathworks.com/support/solutions/data/1-1812J.html>
- Recent Matlabs run Java 5/1.5, but current Java is 6/1.6!
 - Changing version -> more stable, new Java features
 - BUT: Parts of Matlab GUI may not work!!!
 - (NB: 7.6+ is Java 6, though still a private version)

1st thing to know about Java

- Choose your JRE carefully
- Especially with v. < r7.2, TURN OFF JVM for critical applications/resource management
 - Unless, of course, you need Java

Why Java?

- Why use Java instead of Matlab?
 - Everything is compiled
 - Cf non-JIT compliant M-code, will run faster
 - Ie critical loops over objects, pointers, 4-D+ matrices
 - More general programming language
 - Syntax is much cleaner and more powerful, in general
 - Threading!
 - Extensive prebuilt libraries
 - Good for things other than plotting and matrices!

Why Java?

- Why use Java instead of C?
 - Higher level (easier)
 - Native Matlab interface
 - No need to write interface functions and compile explicitly for Matlab in a .mex file
 - Can use native Java syntax directly in Matlab
 - Java objects -> Matlab variables
 - Universal (compile once, run anywhere)
 - Jython?

Using Java

- **EVERYTHING** is an object
- There are no functions, just class methods
- So, we create objects and invoke methods on them
 - Exactly like in Java, but without **new** or type specification

Using Java

- Java path different from Matlab path
 - Can be dynamically used (ie for development)
 - `javaaddpath`, `javarmpath`, `javaclasspath`
 - Static use (faster load times) requires restart
 - `>> edit classpath.txt`
- Either point path to compiled 'classes' folder or directly to *.jar file
- Default Java already on static path; only 3rd party classes must be added

Using Java

- Packages – collections of objects (like folders)
 - We reference an object through its package
 - Eg `java.lang.System.nanoTime()`
 - Or we can import a package/object/method for quick reference, just like in Java
 - `>> import java.lang.*;`
 - `>> System.nanoTime();`

Using Java

- Example: Read URL (modified from help)

```
clear all
clc

url = java.net.URL('http://www.cnn.com');

is = url.openStream();
isr = java.io.InputStreamReader(is);
br = java.io.BufferedReader(isr);

for k = 1:10           % Read the first lines of the webpage
    s = br.readLine();
    disp(s)
end
```

Using Java


- Example: Read URL (modified from help)

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN" "http://  
<meta http-equiv="refresh" content="1800;url=?refresh=1">  
<meta name="Description" content="CNN.com delivers the latest breakin  
<meta name="Keywords" content="CNN, CNN news, CNN.com, CNN TV, news,  
<link rel="alternate" type="application/rss+xml" title="CNN - Top Sto  
<link rel="alternate" type="application/rss+xml" title="CNN - Recent
```

Using Java

- **static** methods can be called without creating an object
 - Can just invoke directly in Matlab
 - Eg >> `java.lang.System.nanoTime()`

`package java.lang` `class System` `static long nanoTime()`
(returns a long integer, ie 64 bit)

The diagram consists of three arrows pointing upwards from the code below to the command above. The first arrow points from 'package java.lang' to 'java.lang' in the command. The second arrow points from 'class System' to 'System' in the command. The third arrow points from 'static long nanoTime()' to 'nanoTime()' in the command.

<http://java.sun.com/j2se/1.5.0/docs/api/java/lang/System.html>

Don't forget `methods('java.lang.System')`, `methodsview(...)`, etc!

Using Java

- For usage and help, see
 - <http://java.sun.com/j2se/1.5.0/docs/api/>
 - <http://java.sun.com/javase/6/docs/api/>

Using Java

- Again, know your JRE

- `>> version -java`

- ans =

- Java 1.5.0_07 with Sun Microsystems Inc. Java
HotSpot(TM) Client VM mixed mode

Writing Java

- <http://java.sun.com/javase/downloads/>
 - Get SDK for Java SE
- Can use notepad to write, but better is:
 - Netbeans
 - www.netbeans.org
 - Eclipse
 - www.eclipse.org
 - Etc

Writing Java

- Make sure to compile for the right version!
 - Remember, Matlab prior to 7.6 runs Java 5
 - JRE's are backwards compatible (5 code runs in 6 JRE) but not forwards compatible

Writing Java

- Again, for details, please follow
 - <http://java.sun.com/docs/books/tutorial/index.html>
- We'll write a very simple HelloWorld app

Writing Java

- HelloWorld.java
 - Take note:
 - Package
 - Declaration
 - **this**
 - Private double
 - Constructor
 - Static void speak
 - Void loop

```
10 package MatlabJava;
11
12 /**
13  *
14  * @author Scott
15  */
16 public class HelloWorld {
17     private double N;
18
19     /** Creates a new instance of HelloWorld */
20     public HelloWorld(double N) {
21         this.N = N;
22     }
23     public static void speak(String str){
24         System.out.println(str);
25     }
26     public void loop(){
27         double a = 0;
28         for(double i = 0; i<this.N; i++){
29             a += i;
30         }
31         System.out.println("Done!");
32     }
33
34 }
```

Writing Java

- To use/test our new class...

If dynamic path classes have changed, cf **clear classes**

```
6 - clear java
7 - javaaddpath('C:\Documents and Settings\Scott\Oro\Java\MatlabJava\build\classes');
```

```
6 - tic;
7 - disp('Hello!!');
8 - MatlabTime = toc;
9
10 - tic;
11 - MatlabJava.HelloWorld.speak('Hello!!');
12 - JavaTime = toc;
13
14 - MatlabFaster = JavaTime/MatlabTime % ~ 250!!!
15
```

≈ 250, due to overhead of switching to Java.
Takes min ~100us to call Java method, more to
pass arguments

Writing Java

- To use/test our new class...

```
N = logspace(1, 9, 30);
JavaFaster = zeros(size(N));

for i = 1:length(N)
    hw = MatlabJava.HelloWorld(N(i));
    tic;
    hw.loop();
    JavaTime = toc;

    tic;
    a = 0;
    for j = 1:N(i)
        a=a+j;
    end
    MatlabTime = toc;

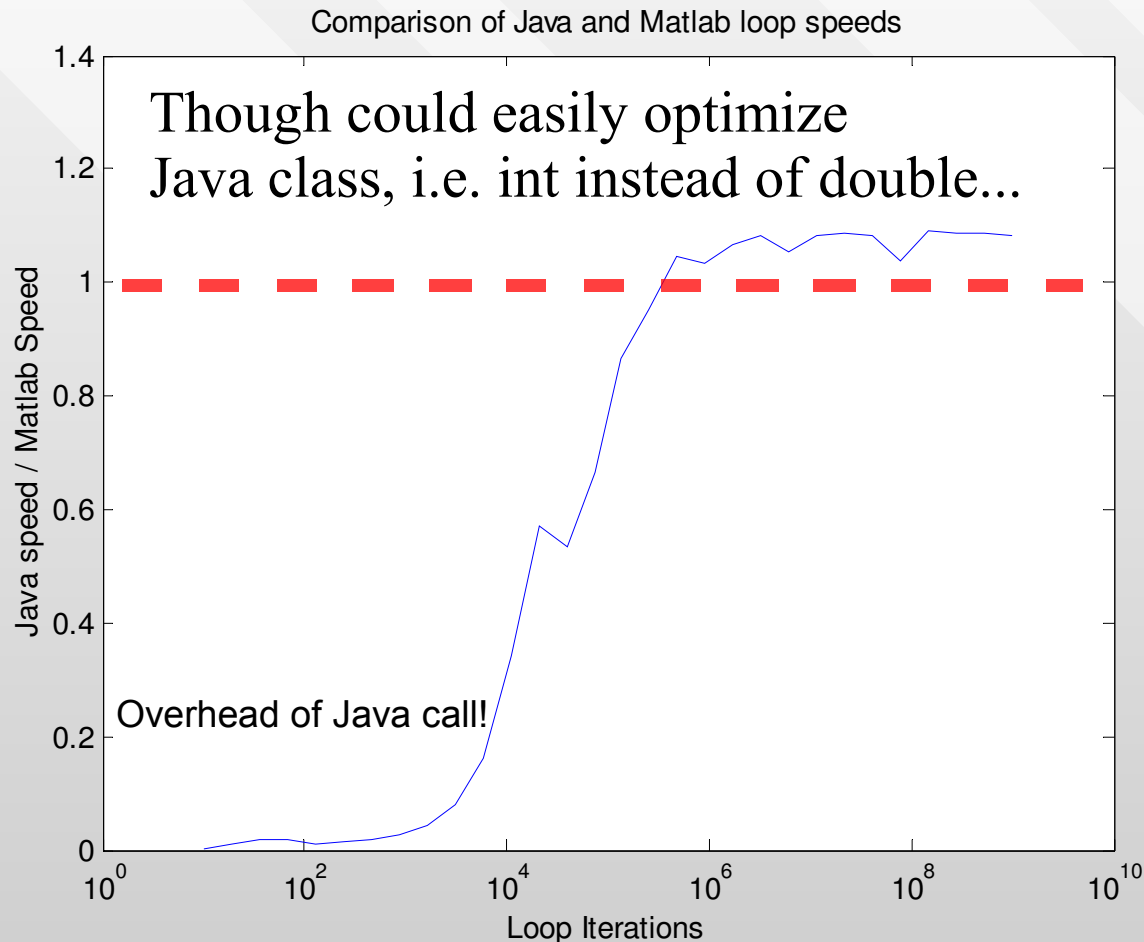
    JavaFaster(i) = MatlabTime/JavaTime;
end

semilogx(N, JavaFaster)
```

Note that `sum(1:N(i))` is not viable here due to large vector size! It will be *much* slower since it has to create the entire array, instead of looping over single numbers in a JIT loop

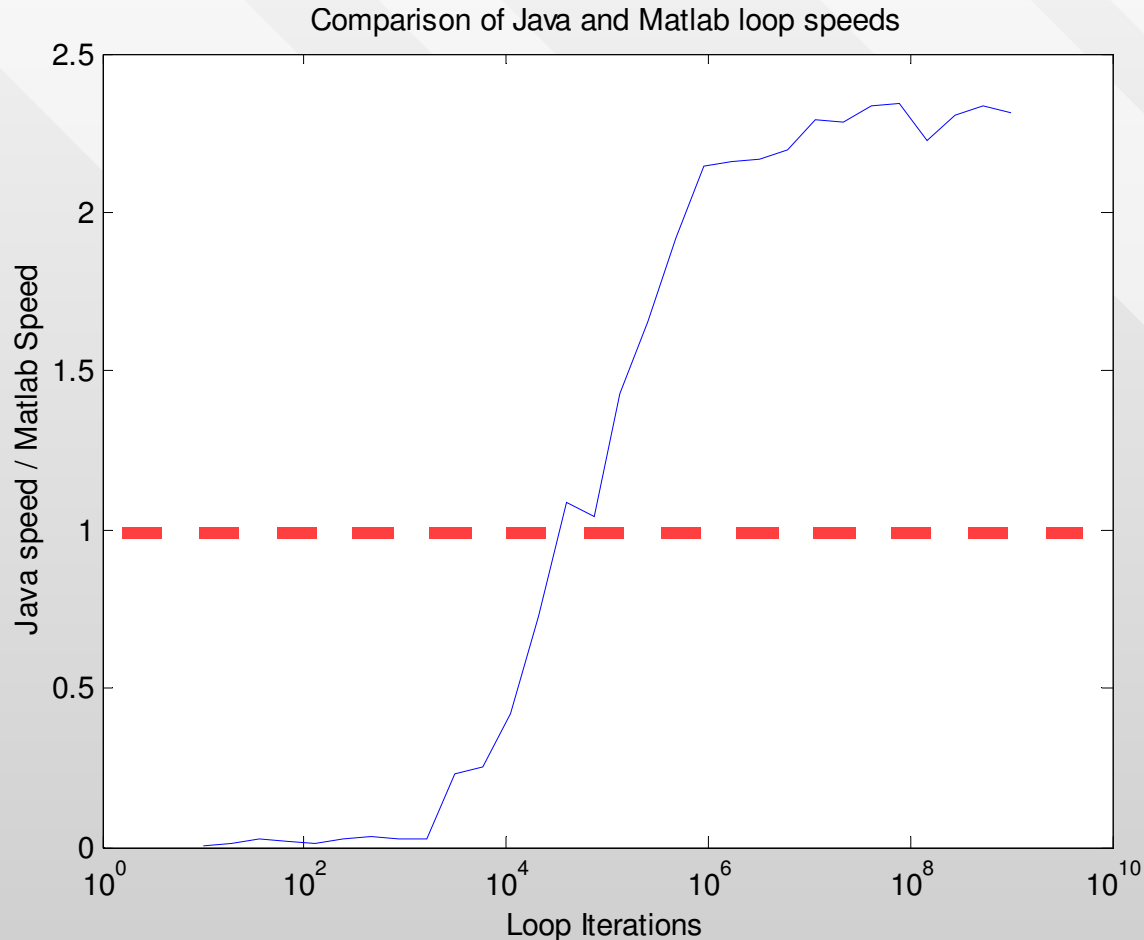
Writing Java

- To use/test our new class...



Writing Java

- Optimized with 32-bit ints (cf 64-bit doubles)



Java Example - RMI

- Remote Method Invocation
 - Java protocol for inter-process communication over TCP/IP (ie, your ethernet card)
 - Allows sharing an object between two JVM's
 - Not the fastest protocol, but a good balance of speed/power/ease of writing

RMI

- We will write a protocol for one Matlab session to invoke commands on another over Java RMI
- MatlabDispatch package online

RMI

- RMI creates a ‘remote object’ which lives in one JVM but its methods can be invoked by another
- We will thus write a remote object which can control a server Matlab’s JVM
- <http://java.sun.com/docs/books/tutorial/rmi/index.html>

MatlabDispatch.MatlabControl

- Uses undocumented com.mathworks.jmi package
- Creates Matlab object which is handle to Matlab running the JVM (or creates a new Matlab session)
- Has methods to invoke 'eval' and 'feval' in Matlab session

```
35 import java.lang.System.*;
36 import com.mathworks.jmi.*;
37
38 public class MatlabControl {
39     Matlab matlab = null; //this is
40     boolean useCb=false;
41     Object returnVal;
42     String callbackFunction;
```

```
84 public void eval(String Command) {
85
86     Matlab.whenMatlabReady(new MatlabEvalCommand(Command,useCb));
87 }
88
89 /**Evaluate a Matlab function that requires arguments. Each element of
90 the "args" vector is an argument to the function "Command"*/
91 public void feval(String Command, Object[] args) {
92     Matlab.whenMatlabReady(new MatlabFevalCommand(Command, args,useCb));
93 }
94
```

MatlabDispatch.Dispatch

- Interface with remote methods:
 - eval, feval, blockingFeval

```
6 package MatlabDispatch;
7
8 public interface Dispatch
9     extends java.rmi.Remote {
10     public void eval(String Command)
11         throws java.rmi.RemoteException;
12
13     public void feval(String Command, Object[] args)
14         throws java.rmi.RemoteException;
15
16     public Object blockingFeval(String Command, Object[] args)
17         throws java.rmi.RemoteException;
18 }
```

MatlabDispatch.MatlabServer

- Create in Server Matlab
- Creates an RMI registry
- Creates a Dispatch object 'd' and shares it through RMI registry

```
21 public class MatlabServer {
22     private Dispatch d;
23     public MatlabServer() {
24         Registry registry;
25         try {
26
27             try{
28                 registry = LocateRegistry.createRegistry(1099);
29             }catch(Exception e){
30                 registry = LocateRegistry.getRegistry();
31             }
32
33
34             d = new DispatchImpl();
35
36             registry.rebind("MatlabServer", d);
37         } catch (Exception e) {
38             System.err.println("Server exception: " + e.toString());
39             e.printStackTrace();
40             System.exit(1);
41         }
42     }
43 }
```

MatlabDispatch.MatlabClient

- Grabs the remote Dispatch object

```
public class MatlabClient {  
    private static Dispatch myDispatch;  
  
    public MatlabClient() {  
        try {  
  
            myDispatch = (Dispatch) Naming.lookup("rmi://localhost/MatlabServer");
```

- Executes remote methods
on a *separate thread*

(could do some optimization
here)

```
58     public void eval(final String Command) {  
59         try {  
60             class Caller extends Thread{  
61                 public void run(){  
62                     try{  
63                         myDispatch.eval(Command);  
64                     } catch(Exception e){  
65                         System.out.println(e.toString());  
66                     }  
67                 } }  
68  
69                 Caller c = new Caller();  
70                 c.start();  
71             } catch (Exception e) {  
72                 System.err.println("MatlabClient exception:");  
73                 e.printStackTrace();  
74             }  
75         }  
--
```

Using MatlabDispatch

- Function createRMIServer

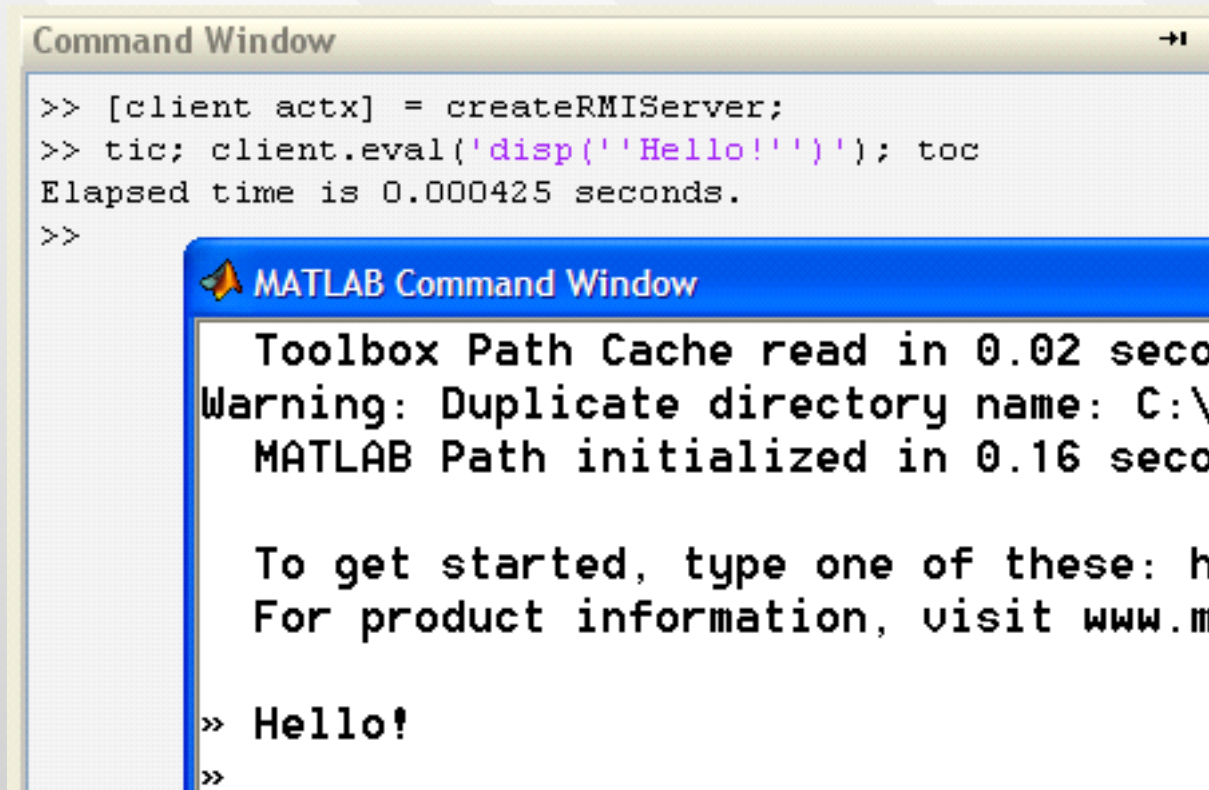
```
1 function [client actx] = createRMIServer
2 % [client actx] = createRMIServer
3 %
```

- Creates an Automation Server, and a MatlabServer object inside, then a MatlabClient object

```
40 - actx = actxserver('matlab.application');
41 - actx.Execute('MatlabServer = MatlabDispatch.MatlabServer');
42 - client = MatlabDispatch.MatlabClient;
43
44 - end
```

Using MatlabDispatch

- Much faster than COM (can even do better)



```
Command Window
>> [client actx] = createRMIServer;
>> tic; client.eval('disp(''Hello!'')'); toc
Elapsed time is 0.000425 seconds.
>>
```

MATLAB Command Window

```
Toolbox Path Cache read in 0.02 seconds
Warning: Duplicate directory name: C:\
MATLAB Path initialized in 0.16 seconds

To get started, type one of these: h
For product information, visit www.m

>> Hello!
>>
```

Using MatlabDispatch

- Benefits of RMI
 - Fast Java communication protocol
 - Can also work over network
 - Can control other Java objects as well
 - Remote JRE doesn't have to match Matlab's!
- <http://java.sun.com/docs/books/tutorial/rmi/index.html>

Broadcast Info

- **Datagrams/UDP: Fast internet broadcast protocol**
 - This drives streaming audio/video downloads
 - Faster than RMI but not marshaled (prone to errors)
 - One-way communication

UDP

- DatagramSockets (snippets of useful code)

```
307 public streamHUD(){
308     try{
309
310         udp = new DatagramSocket();
311         p = new DatagramPacket(new byte[100], 100, getBroadcast(InetAddress.getLocalHost()), HUD_BROADCAST_PORT);
312
313     } catch (Exception e){
314         System.err.println(e);
315     }
316 }
317
318 }
319 public synchronized void stream(int field, String str){
320     try{
321         byte_out.reset();
322         data_out.write(field);
323         data_out.writeUTF(str);
324         p.setData(byte_out.toByteArray());
325         p.setLength(p.getData().length);
326
327         udp.send(p);
328     } catch (Exception e){
329         System.out.println(e);
330     }
331 }
332 }
```

UDP

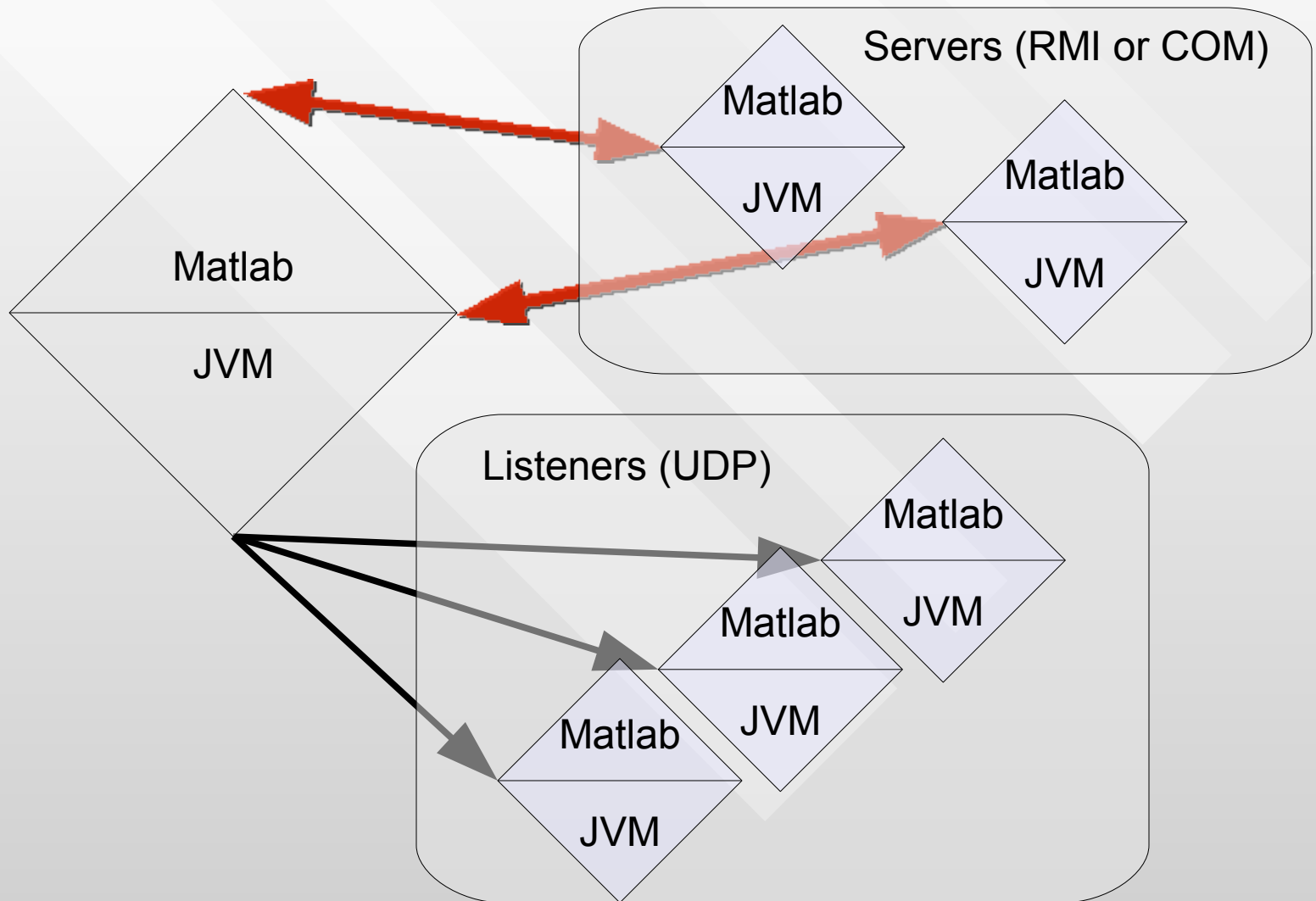
- Listeners (can be more than one computer)

```
911 private class HUD_DataListener extends Thread {
912
913     private DatagramPacket p = new DatagramPacket(new byte[200], 200);
914     private ByteArrayInputStream byte_in = new ByteArrayInputStream(p.getData());
915     private DataInputStream ds = new DataInputStream(byte_in);
916     private MulticastSocket udp;
917     private InetAddress host;
918
919     public HUD_DataListener() {...}
927     public HUD_DataListener(InetAddress remotehost) {...}
931     public int getPort() {...}
931     public synchronized void run() {
935         try {
936             udp = new MulticastSocket(HUDclient.HUD_BROADCAST_PORT);
937             udp.joinGroup(HUDclient.getBroadcast(host));
938
939             // Polls socket and does stuff
940             while(true) {
941
942                 udp.receive(p);
943                 output(ds.read(), ds.readUTF().toCharArray());
944
945                 byte_in.reset();
946             }
947
948             } catch (Exception e) {
949                 e.printStackTrace();
950             }
951     }
952 }
```

UDP

- Now we are streaming Matlab data over the web!
- I watch my subjects on my laptop while they work in another room

Schematic RMI/UDP



More Java extensions

- Swing
 - Full-blown GUI application
- Threading/threadlocks
- Webservice providers, AJAX, XML...
- Dynamic class construction (can return to Matlab!)
- Static memory optimizations
- 3d graphics/OpenGL/Video rendering
- HDTV?

More Advanced Matlab

- GUI programming
 - (though better in Java!)
- MEX extensions in C
- Handle callback functions/notifications
- Figure rendering tricks/realtime drawing
- Compiling for MCR/building for Java
- Regex
- CUDA/GPU programming
 - Jacket: <http://www.accelereyes.com/>
- Your favorite toolbox...

That's all!

- Give yourselves a hand...
- Please complete exit survey online:
 - http://www.surveymonkey.com/s.aspx?sm=gP74Ux2ZvrHqpCuR72lNow_3d_3d
 - Link posted on Stellar page