

## Administrivia

- Reminder: First installment of Homework 1 (OpenMP program and discussion) due today.

Slide 1

## Review of Useful Unixisms

- Remember that you can capture output of program `foo` in file `foo.out` by typing:  
`foo >foo.out` (to overwrite)  
`foo >>foo.out` (to append)  
Append `2>&1` to capture standard error too.
- You can have output go both to the screen and a file by typing:  
`foo | tee foo.out` (to overwrite)  
`foo | tee -a foo.out` (to append)
- Remember that if you have commands you want to execute multiple times, you can make a script — e.g., put the commands in file `bar` and execute by typing `sh bar`.
- If you're using `vim` to edit code and finding it painful — try spending half an hour with the tutorial (command `vimtutor`).

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### Parallel Programming in Java

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- Java supports multithreaded (shared-memory parallel) programming as part of the language — `synchronized` keyword, `wait` and `notify` methods of `Object` class, `Thread` class. Programs that use the GUI classes (AWT or Swing) multithreaded under the hood. Justification probably has more to do with hiding latency than HPC, but still useful, and latest version (5.0) includes much new library stuff.
- Java also provides support for forms of distributed-memory programming, through library classes for networking, I/O (`java.nio`), and Remote Method Invocation (RMI).

### What Does A Multithreaded Java Program Look Like?

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- Easy answer: Like a regular Java program. (In fact, any program with a GUI ...)
- Programming model: All threads share a common address space. Programmer is responsible for creating threads, providing synchronization, etc.

### Creating Threads in Java

- Threads are all instances of `Thread` class (or a subclass). Pre-5.0, two ways to create threads:

- Create a subclass of `Thread` (frowned on by o-o purists).
- Create a `Thread` using an object that implements `Runnable` (preferable).

Either way, `run` method (of subclass of `Thread`, or of `Runnable`) contains code for thread to execute.

- Start thread with `start` method. Can wait for it to finish with `join`.
- “Hello world” example (`Hello1.java` and `Hello2.java` on sample programs page).

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### Shared Variables in Java

- Code executed by a thread is some object's `run` method. Access to variables is consistent with usual Java scoping — class/instance variables, parameters, etc.
- As we noted before, though, simultaneous access to shared variables can be risky, however. So . . .

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## Synchronization in Java

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- Interaction among threads in Java based on “monitor” idea (Hoare (1975) and Brinch Hansen (1975)).
- Every object has implicit lock; `synchronized` keyword means “only run this when you have the relevant lock” — if another thread has the lock, wait. Can be used to ensure one-at-a-time access to critical variables.  
“Relevant lock”? For synchronized methods, lock for object (instance methods) or class (static methods). For synchronized blocks, you specify the object.  
Example — `HelloSynch.java` on sample programs page.
- `wait` and `notify` methods allow more interesting kinds of coordination (next time).

## Minute Essay

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- `synchronized` can avoid problems with shared variables. Can you think of problems this might introduce?