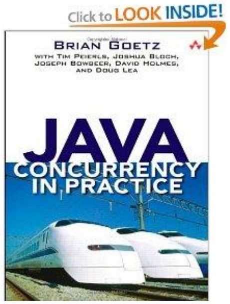
Introduction to Concurrency

4010-441
Principles of Concurrent System Design

Logistics (On myCourses)

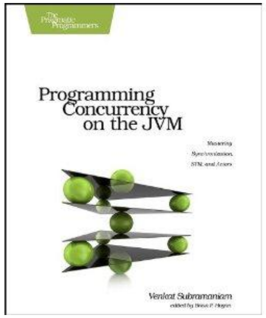


Texts

- *Java Concurrency in Practice*, Brian Goetz, et. al.
- *Programming Concurrency on the JVM*, Venkat Subramaniam.

Rough Calendar

- 4 weeks on controlling shared, mutable state + 1 exam + project
- 2 weeks on actors + 1 exam + project
- 1.5 weeks on (software) transactional memory
- 1.5 weeks on classic concurrency problems
- 1 week on other approaches to concurrency



Grading

- (5%) Preparation & Presentation
- (15%) Activities (2-3 persons for a week or less)
- (30%) Two projects (15% lowest each)
- (30%) Two in-class exams (15% each)
- (20%) Final exam in finals week

Projects

- 4-5 persons for 2+ weeks
- I'll pick the teams
- You'll have an opportunity to assess the contributions of your teammates via Peer2Peer.
- Individual grade is team grade, adjusted as appropriate based on peer evaluations.

Activities

- 2-3 persons for <= 1 week
- I'll pick the teams - sub-teams of projects where feasible
- Always traded on a 10 point basis

Preparation & Participation

- Do the readings before the specified due date
- I'll consider participation in answering questions and engaging in discussions.
- In participating in discussions, I will ***never*** penalize you for a “wrong” answer (unless you're flippant).
- Woody Allen: 80% of success is showing up.

Now on to the good stuff!

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A process has a self-contained execution environment. A process generally has a complete, private set of basic run-time resources; in particular, each process has its own memory space.

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What Is a Thread?

Threads exist within a process — every process has at least one. Threads share the process's resources, including memory and open files. This makes for efficient, but potentially problematic, communication.

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- Original (OS centric processes)
  - Better resource utilization.
  - Fairness among multiple users with multiple computations.
- Current (process centric threads)
  - Exploiting multiple processors
  - Moore's Law running out of steam (multi-core).
  - Modeling: Divide & conquer on loosely related tasks.
  - Simplify handling asynchronicity (e.g., mouse events)
  - Throughput (even on single CPU systems)
  - Responsiveness

The Perils of Concurrency

- Safety: Nothing bad happens
  - Incorrect behavior in context of concurrency
  - Race conditions
  - Memory barrier (caching)
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- Performance
  - TANSTAAFL (There Ain't No Such Thing As A Free Lunch)
  - Context switching overhead
  - Disabled compiler optimizations

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- Testing, hair-pulling, and Heisenbugs

The Perils of Concurrency

- **1985-1987 -- Therac-25 medical accelerator.** A radiation therapy device malfunctions and delivers lethal radiation doses at several medical facilities. Based upon a previous design, the Therac-25 was an "improved" therapy system that could deliver two different kinds of radiation: either a low-power electron beam (beta particles) or X-rays. The Therac-25's X-rays were generated by smashing high-power electrons into a metal target positioned between the electron gun and the patient. A second "improvement" was the replacement of the older Therac-20's electromechanical safety interlocks with software control, a decision made because software was perceived to be more reliable.
- What engineers didn't know was that both the 20 and the 25 were built upon an operating system that had been kludged together by a programmer with no formal training. Because of a subtle bug called a "race condition," a quick-fingered typist could accidentally configure the Therac-25 so the electron beam would fire in high-power mode but with the metal X-ray target out of position. At least five patients die; others are seriously injured.

(Source: “History's Worst Software Bugs”, Wired)

The Ultimate Culprit - Shared, Mutable State

- Most of your development has been in imperative languages.
- The fundamental operation is assignment to change state.
  - Assignable variables are mutable.
  - May be exposed as public (bad karma).
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```
public class Counter {
   private int count = 0 ;

   public void increment() {
      count = count + 1 ;
   }

   public int getCount() {
      return count ;
   }
}
```

If we call **increment()** 10,000 times and then call **getCount()**, what value is returned?

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- Three basic approaches:
  - Make things immutable.
  - Hide shared state behind sequential access.
  - Provide mechanisms to support controlled access to shared, mutable state.

Other Issues

- Thread management
  - How many threads at one time?
  - Allocation of tasks to threads.
  - Thread scheduling.
- Higher level constructs
  - Fork / join
  - Callables & Futures
- Distributed state management
  - State consistency
  - Decision consensus