Lecture 26: Parallelism I

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Some slides based on those from Dan Grossman, U. of Washington
The story so far assumed...

- **Sequential programming**: everything is part of one sequence and happens one thing at a time
  - E.g., in Java start at `main()`, one assignment/call/return/arithmetic operation at a time
Multi-threaded programming

In *multi-threaded programming* we need to rethink:

- **Programming**: work is divided among threads of execution that need to be coordinated (*synchronized*)
- **Algorithms**: parallelism increases the work done per unit time (*throughput*)
- **Data Structures**: need to provide *concurrent* access if multiple threads access the same data
A simplified view of history

• Writing correct and efficient multithreaded code is often much more difficult than sequential code
  • Especially in common languages like Java and C
  • So typically stay sequential if possible

• From roughly 1980-2005, desktop computers got twice as fast every couple years at running sequential programs

• But nobody knows how to continue this
  • Increasing clock rate generates too much heat
  • Relative cost of memory access is too high
  • But we can keep making “wires exponentially smaller” (Moore’s “Law”), so put multiple processors on the same chip (“multicore”)
What can we do with multiple cores?

• Run multiple totally different programs at the same time
  • Already doing that, but with time-slicing
• Do multiple things at once in one program
  • Our focus – more difficult
  • Requires rethinking everything from asymptotic complexity to how to implement data-structure operations
Parallelism vs Concurrency – Separate Terms

- **Parallelism**: Use extra resources to solve a problem faster
- **Concurrency**: Correctly and efficiently manage shared resources

**Common ground:**
- They both use threads
- If parallel computations need access to shared resources, then the concurrency needs to be managed
Parallelism

Recipe – Step 1

Recipe – Step 2

Recipe – Step 3

Sometimes we might have to wait for one cook to finish their step
Concurrency

How do we handle access to a common resource?

Recipe – Step 1

Recipe – Step 2

Recipe – Step 3
Program state in sequential programming

Calling a method pushes a new frame
Returning from a method pops it

Heap holds objects, instance variables, and static variables
Multiple Threads/Processors Model

- A set of threads, each with its own call stack & program counter
- No access to another thread’s local variables
- Threads can (implicitly) share static fields / objects
- To communicate, write somewhere another thread reads
Shared memory

Threads, each with own unshared call stack & current statement

- (pc for “program counter”)
- local variables are primitives, \texttt{null}, or heap references
Program state in parallel programming

When a new thread runs, it has its own call stack.