Lecture 18
Parallelization and Dependent Tasks
Recall Parallelization of Sequential Algorithms

• Goal of parallelization: make algorithms run faster by performing computations in parallel

• Tasks give a framework for studying parallelism
  – Tasks are (often) independent
  – They can therefore be done in parallel
  – When tasks are independent, performance tuning can be done by:
    • Restricting number of threads in thread pools
    • Relaxing task boundaries so that overhead associated with task management is kept reasonable
  – Example: Quicksort
What About Dependent Tasks?

• Traditional issue: *thread-starvation deadlock*
  – Tasks being executed in a thread pool can block waiting for their dependents
  – If more tasks block than there are threads: deadlock

• But: if you make number of threads unbounded, this may have a negative effect on performance
  – Thread creation imposes overhead itself
  – Benefit of thread limits: bound this overhead
### Example: Mergesort

- Another commonly used sorting algorithm
- Basic strategy
  - Split array into two subarrays
  - Recursively sort each subarray
  - Merge sorted subarrays into one sorted list
- Often used for secondary-storage sorting
  - Do not need to store entire arrays in main memory
  - Do not need “random access” to elements being sorted
How To Parallelize Mergesort?

• Basic strategy for recursive algorithms
  – Make recursive calls tasks
  – When algorithm is tail-recursive, this works very well
    • No need to wait for tasks to complete after spawning them
    • Thus, tasks that creates subtasks can be allowed to terminated

• Problem with Mergesort: it is not tail-recursive
  – After recursive calls (sorting of sublists) terminate, there is more work to be done (merging)
  – This means tasks that creates subtasks must wait for results
Mergesort and Thread-Starvation Deadlock

• Because of task dependencies in Mergesort, thread-starvation deadlock can happen!
  – Suppose the thread pool contains a fixed number of worker threads
  – If number of pending sorting tasks is greater than number of workers, then workers may all be occupied by tasks awaiting completion of subtasks

• For algorithms like Mergesort, it is unsafe to use fixed-size thread pools
  – Use unbounded ones, like cached thread pool returned by `Executors.newCachedThreadPool()`
  – Then deadlock problem cannot arise
  – But what about performance? Isn’t thread overhead a problem?
Performance Tuning for Tasks with Dependencies

- Can still use same strategy for performance tuning of tail-recursive algorithms!
  - Identify threshold for problem size below which sequential algorithm is used
  - For problems larger than threshold size:
    - Break problem into sub-problems
    - Create tasks for sub-problems
    - Give tasks to executor
    - Take results of subtasks, assemble final solution (this step is not needed when algorithm is tail-recursive)

- Limits on number of worker threads in this case is enforced indirectly by problem-size threshold, rather than directly via thread-pool size limit
ParallelMergeSortTunable.java

• Parallel implementation of mergesort
• Non-fixed-size executor used to avoid thread-starvation deadlock
• Threshold used to determine when to switch to sequential sorting