

# COMP 322: Fundamentals of Parallel Programming

## Lecture 9: Java's ForkJoin Library

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# Worksheet #8: Classifying different versions of parallel search algorithms

Enter "YES" or "NO", as appropriate, in each box below

Example: String Search variation	Data Race Free?	Functionally Deterministic?	Structurally Deterministic?
V1: Count of all occurrences	YES	YES	YES
V2: Existence of an occurrence	NO	YES	YES
V3: Index of any occurrence	NO	NO	YES
V4: Optimized existence of an occurrence: do not create more async tasks after occurrence is found	NO	YES	NO
V5: Optimized index of any occurrence: do not create more async tasks after occurrence is found	NO	NO	NO



# Updating all Elements in an Array

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- Suppose we have a large array  $a$  of integers
- We wish to update each element of this array:
  - $a[i] = a[i] / (i + 1)$
- How would we write this as a parallel program using `async` and `finish`?



# Recursive Decomposition

```
solve(problem)
  if problem smaller than threshold
    solveDirectly(problem)
  else
    in parallel:
      l = solve(left-half)
      r = solve(right-half)
    combine(l, r)
```

- In general, can create more than 2 sub-problems
- combine then needs to handle all the sub-problems



# Update using async and finish

```
1. sequentialUpdate(a, lo, hi)
2.     for (i = lo; i < hi; i++)
3.         a[i] = a[i] / (i + 1)
4.
5. parallelUpdate(a, lo, hi)
6.     if (hi - lo) < THRESHOLD
7.         sequentialUpdate(a, lo, hi)
8.     else
9.         mid = (lo + hi) / 2
10.         finish
11.         async parallelUpdate(a, lo, mid)
12.         async parallelUpdate(a, mid, hi)
```



# Task Parallelism Using Standard JDK Libraries

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- Thread objects (prior to JDK 5)
  - Start Runnable task  $t$  with *`new Thread(t).start()`*
  - Create new Thread each time parallel task needs to be done
- Executors (JDK 5)
  - Handles thread management with thread pools
  - Use *`execute(t)`* to start a task  $t$  with no return value
  - `ExecutorService` allows for tasks with return values (futures)
- ForkJoinTasks (JDK 7) useful for divide and conquer problems
  - Implements work-stealing
- HJLib (JDK 8)



# Using Java's Fork/Join Library

We can perform recursive subdivision using the Fork/Join libraries provided in the JDK as follows:

```
public abstract class RecursiveAction extends
ForkJoinTask<Void> {
    protected abstract void compute();
    ...
}
public abstract class RecursiveTask<V> extends
ForkJoinTask<V> {
    protected abstract V compute();
    ...
}
```



# RecursiveAction Subclass

```
1.class DivideTask extends RecursiveAction {
2.    static final int THRESHOLD = 5;
3.    final long[] array;
4.    final int lo, hi;
5.
6.    DivideTask(long[] array, int lo, int hi) {
7.        this.array = array;
8.        this.lo = lo;
9.        this.hi = hi;
10.   }
11.   protected void compute() {...} // next slide
12. }
```





# compute()

```
1. protected void compute() {
2.     if (hi - lo < THRESHOLD) {
3.         for (int i = lo; i <= hi; ++i)
4.             array[i] = array[i] / (i + 1);
5.     } else {
6.         int mid = (lo + hi) >>> 1;
7.         invokeAll(new DivideTask(array, lo, mid),
8.                 new DivideTask(array, mid+1, hi));
9.     }
10. }
```



# ForkJoinTask<V>

- Similar to a finish block enclosing a collection of asyncs
- Other Fork/Join methods in superclass ForkJoinTask<V>

```
class ForkJoinTask<V> extends Object
    implements Serializable, Future<V>
{
    ForkJoinTask<V> fork()    // parallel execution
    V join()                 // returns result when execution completes
    V invoke()               // forks, joins, returns result
    static void invokeAll(ForkJoinTask<?> t1, ForkJoinTask<?> t2)
        ...
}
```



# ForkJoinTasks and Futures

- ForkJoinTasks implement the Future interface
- Acts very much like HJLib futures

```
interface Future<V> {  
    V get()  
    V get(long timeout, TimeUnit unit)  
    boolean cancel(boolean interruptIfRunning)  
    boolean isCancelled()  
    boolean isDone()  
}
```



# Recursive Array Sum using HJlib

```
1. protected double computeSum(  
2.     final double[] xArray, final int start, final int end)  
3.     throws SuspendableException {  
  
5.     if (end - start < THRESHOLD) {  
  
7.         // sequential threshold cutoff  
8.         return seqArraySum(xArray, start, end);  
  
10.    } else {  
11.        int mid = (end + start) / 2;  
  
13.        HjFuture<Double> leftFuture = future() -> {  
14.            return computeSum(xArray, start, mid);  
15.        });  
16.        HjFuture<Double> rightFuture = future() -> {  
17.            return computeSum(xArray, mid, end);  
18.        });  
19.        return leftFuture.get() + rightFuture.get();  
20.    } }
```



# Recursive Array Sum using ForkJoinTasks

```
1. protected static class ArraySumForkJoinTask
2.     extends RecursiveTask<Double> {
3.     ...
4.     protected Double compute() {
5.         if (end - start < THRESHOLD) {
6.             // sequential threshold cutoff
7.             return seqArraySum(xArray, start, end);
8.         } else {
9.             final int mid = (end + start) / 2;
10.            final ArraySumForkJoinTask taskLeft =
11.                new ArraySumForkJoinTask(xArray, start, mid);
12.            final ArraySumForkJoinTask taskRight =
13.                new ArraySumForkJoinTask(xArray, mid, end);
14.
15.            // Is there anything wrong with the code below?
16.            taskLeft.fork();
17.            return taskLeft.join() + taskRight.compute();
18.        } } }
```



# Announcements & Reminders

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- Quiz for Unit 2 (topics 2.1 - 2.8) will be available on Canvas, due Friday, Feb. 19th at 11:59pm

