Lecture 15: Point-to-Point Synchronization with Phasers

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For the example below, will reordering the five async statements change the meaning of the program (assuming that the semantics of the reader/writer methods depends only on their parameters)? If so, show two orderings that exhibit different behaviors. If not, explain why not.

No, reordering the asyncs doesn't change the meaning of the program. Regardless of the order, Task 3 will always wait on Task 1. Task 5 will always wait on Task 2. Task 4 will always wait on both Task 1 and 2.

1. `DataDrivenFuture left = new DataDrivenFuture();`
2. `DataDrivenFuture right = new DataDrivenFuture();`
3. `finish {`
4. `async await(left) leftReader(left); // Task3`
5. `async await(right) rightReader(right); // Task5`
6. `async await(left,right)`
7. `bothReader(left,right); // Task4`
8. `async left.put(leftWriter()); // Task1`
9. `async right.put(rightWriter()); // Task2`
10. `}`
Question: when can the point-to-point computation graph result in a smaller CPL than the barrier computation graph?
Phasers: a unified construct for barrier and point-to-point synchronization

- HJ phasers unify barriers with point-to-point synchronization
  - Inspiration for java.util.concurrent.Phase
- Previous example motivated the need for “point-to-point” synchronization
  - With barriers, phase i of a task waits for all tasks associated with the same barrier to complete phase i-1
  - With phasers, phase i of a task can select a subset of tasks to wait for
- Phaser properties
  - Support for barrier and point-to-point synchronization
  - Support for dynamic parallelism --- the ability for tasks to drop phaser registrations on termination (end), and for new tasks to add phaser registrations (async phased)
  - A task may be registered on multiple phasers in different modes
Simple Example with Four Async Tasks and One Phaser

1. `finish(() -> {
2.     ph = new Phaser(SIG_WAIT); // mode is SIG_WAIT
3.     asyncPhased(ph.inMode(SIG), () -> {
4.         // A1 (SIG mode)
5.         doA1Phase1(); next(); doA1Phase2(); });
6.     asyncPhased(ph.inMode(SIG_WAIT), () -> {
7.         // A2 (SIG_WAIT mode)
8.         doA2Phase1(); next(); doA2Phase2(); });
9.     asyncPhased(ph.inMode(HjPhaserMode.SIG_WAIT), () -> {
10.        // A3 (SIG_WAIT mode)
11.        doA3Phase1(); next(); doA3Phase2(); });
12.     asyncPhased(ph.inMode(HjPhaserMode.WAIT), () -> {
13.        // A4 (WAIT mode)
14.        doA4Phase1(); next(); doA4Phase2(); });
15. });
"}
Semantics of *next* depends on registration mode

- **SIG\_WAIT**: \( \text{next} = \text{signal} + \text{wait} \)
- **SIG**: \( \text{next} = \text{signal} \)
- **WAIT**: \( \text{next} = \text{wait} \)
Summary of Phaser Construct

- Phaser allocation
  - HjPhaser ph = newPhaser(mode);
  - Phaser ph is allocated with registration mode
  - Phaser lifetime is limited to scope of Immediately Enclosing Finish (IEF)

- Registration Modes
  - HjPhaserMode.SIG, HjPhaserMode.WAIT,
    HjPhaserMode.SIG_WAIT, HjPhaserMode.SIG_WAIT_SINGLE
  - NOTE: phaser WAIT is unrelated to Java wait/notify (which we will study later)

- Phaser registration
  - asyncPhased (ph1.inMode(<mode1>), ph2.inMode(<mode2>), ... () -> <stmt> )
  - Spawned task is registered with ph1 in mode1, ph2 in mode2, ...
  - Child task’s capabilities must be subset of parent’s
  - asyncPhased <stmt> propagates all of parent’s phaser registrations to child

- Synchronization
  - next();
  - Advance each phaser that current task is registered on to its next phase
  - Semantics depends on registration mode
  - Barrier is a special case of phaser, which is why next is used for both
A task can be registered in one of four modes with respect to a phaser: SIG_WAIT_SINGLE, SIG_WAIT, SIG, or WAIT. The mode defines the set of capabilities — signal, wait, single — that the task has with respect to the phaser. The subset relationship defines a natural hierarchy of the registration modes. A task can drop (but not add) capabilities after initialization.

- SIG_WAIT_SINGLE = \{ signal, wait, single \}
- SIG_WAIT = \{ signal, wait \}
- SIG = \{ signal \}
- WAIT = \{ wait \}
Left-Right Neighbor Synchronization (with m=3 tasks)

```java
finish(() -> { // Task-0
    final HjPhaser ph1 = new Phaser(SIG_WAIT);
    final HjPhaser ph2 = new Phaser(SIG_WAIT);
    final HjPhaser ph3 = new Phaser(SIG_WAIT);
    asyncPhased(ph1.inMode(SIG), ph2.inMode(WAIT),
                () -> { doPhase1(1);
                        next(); // signals ph1, waits on ph2
                        doPhase2(1);
                        }); // Task T1
    asyncPhased(ph2.inMode(SIG), ph1.inMode(WAIT), ph3.inMode(WAIT),
                () -> { doPhase1(2);
                        next(); // signals ph2, waits on ph3
                        doPhase2(2);
                        }); // Task T2
    asyncPhased(ph3.inMode(SIG), ph2.inMode(WAIT),
                () -> { doPhase1(3);
                        next(); // signals ph3, waits on ph2
                        doPhase2(3);
                        }); // Task T3
}); // finish
```
Computation Graph for $m=3$ example (without async-finish nodes and edges)
forallPhased barrier is just an implicit phaser!

1. `forallPhased(iLo, iHi, (i) -> {`
2. `S1; next(); S2; next();{...}`
3. `});`

is equivalent to

1. `finish(() -> {`
2. `// Implicit phaser for forall barrier`
3. `final HjPhaser ph = newPhaser(SIG_WAIT);`
4. `forseq(iLo, iHi, (i) -> {
5. `asyncPhased(ph.inMode(SIG_WAIT), () -> {
6. `S1; next(); S2; next();{...}
7. `}); // next statements in async refer to ph
8. `});`