COMP 322: Fundamentals of Parallel Programming

Lecture 2: Task Creation and Termination using Async & Finish

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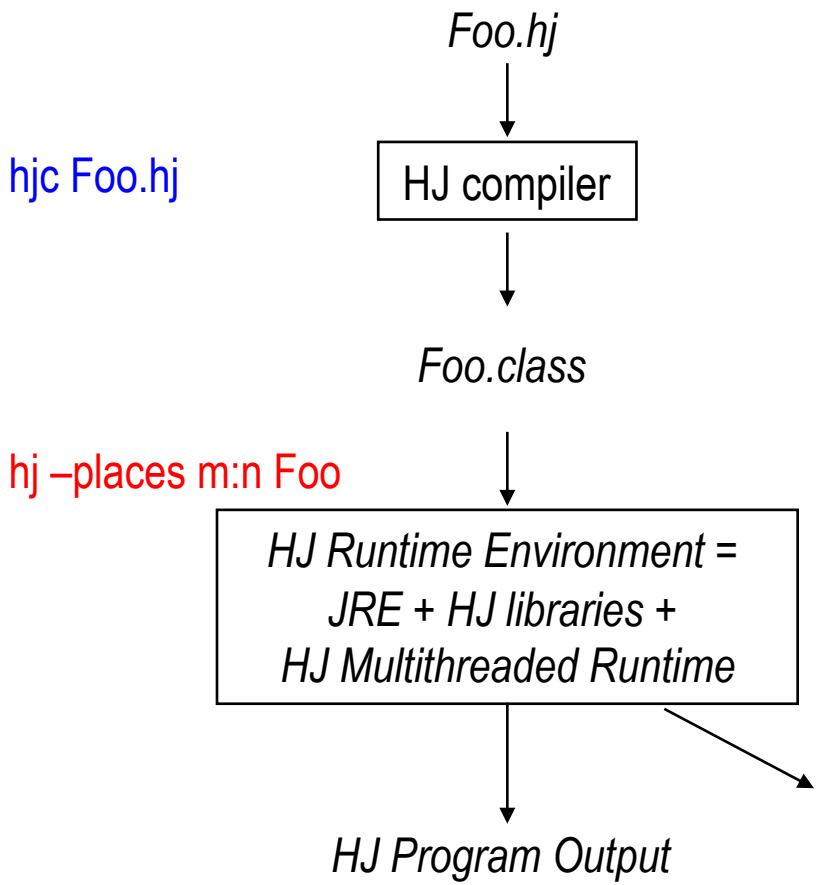
Acknowledgments for Today's Lecture

- COMP 322 Lecture 2 handout

Habanero-Java (HJ) Language

- HJ is a new language developed in the Rice Habanero Multicore Software research project
  - Derived from IBM's Java-based X10 v1.5 implementation in 2007
  - HJ is an extension of Java 1.4
    - Java 5 & 6 *language* features (generics, metadata, etc.) are currently not supported by the HJ front-end
    - However, Java 5 & 6 libraries and classes can be called from HJ programs
      - Just don't call a method that performs a blocking operation because that will mess up the HJ scheduler!
- Four classes of parallel programming primitives in HJ:
  1. Dynamic task creation & termination: forall, async, finish, get
  2. Mutual exclusion and isolation: isolated
  3. Collective and point-to-point synchronization: phaser, next
  4. Locality control --- task and data distributions: places, here

HJ Compilation and Execution Environment



HJ source program --- must contain a class named Foo with a public static void main(String[] args) method

HJ compiler translates Foo.hj to Foo.class, and inserts calls to HJ runtime as needed

HJ runtime allocates m*n worker threads across m "places" (default values: m = 1, n = 3)

HJ Abstract Performance Metrics
(optional, enabled by –perf=true *option for hj command)*

Caveat: this is a research prototype with known limitations. Please report bugs and suggestions to comp322-staff@mailman.rice.edu.

Async and Finish Statements for Task Creation and Termination (Recap)

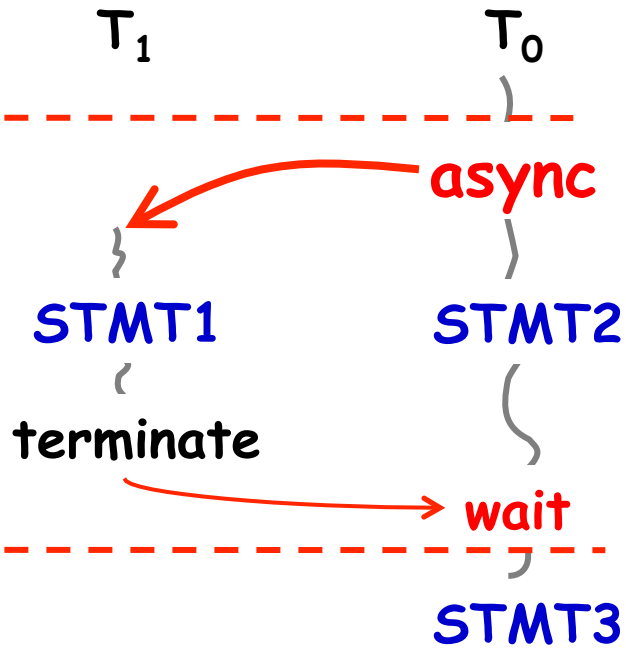
async S

- Creates a new child task that executes statement S
- Parent task immediately continues to statement following the async

finish S

- Execute S, but wait until *all* (transitively) spawned asyncs in S's scope have terminated.
- Implicit finish between start and end of main program

```
//Task T0 (Parent)
finish {    //Begin finish
  async
    STMT1;  //T1 (Child)
  //Continuation
  STMT2;    //T0
} //Continuation //End finish
STMT3;      //T0
```



Async Example #1

```
// Example 1: execute iterations of a counted for loop in parallel
// (we will later see forall as a shorthand for this common case)
for (int i = 0; i < A.length; i++)
  async { A[i] = B[i] + C[i]; }
```


Async Example #2

```
// Example 2: execute iterations of a while loop in parallel
p = first;
while ( p != null ) {
  async { p.x = p.y + p.z; }
  p = p.next;
}
```

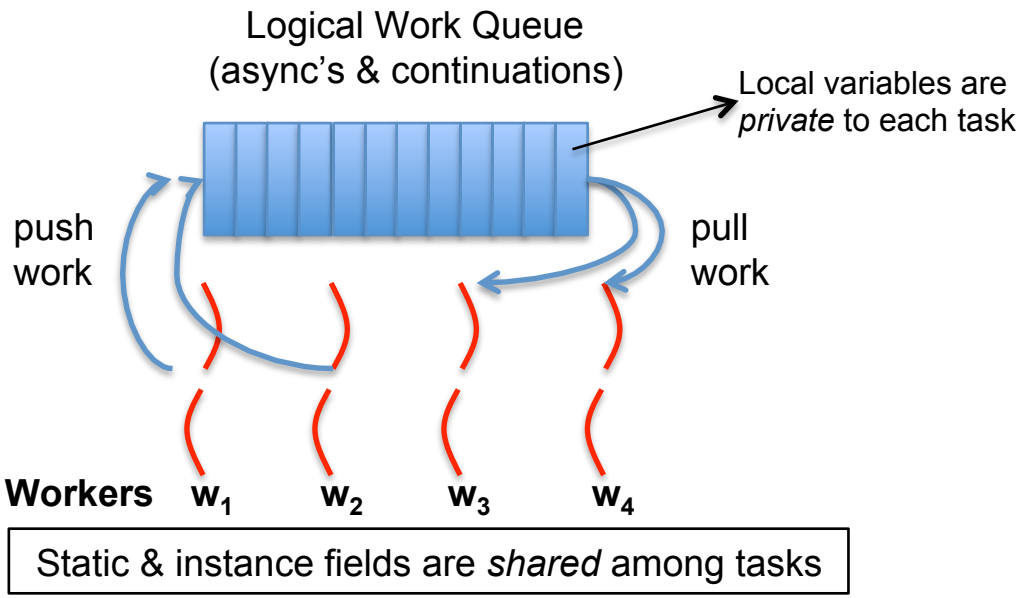

Async Example #3

```
// Example 3: Example 2 rewritten as a recursive method
static void process(T p) {
  if ( p != null ) {
    async { p.x = p.y + p.z; }
    process(p.next);
  }
}
```


Async Example #4

```
// Example 4: execute method calls in parallel
async left_s = quickSort(left);
async right_s = quickSort(right);
```


Scheduling HJ tasks on processors in a parallel machine

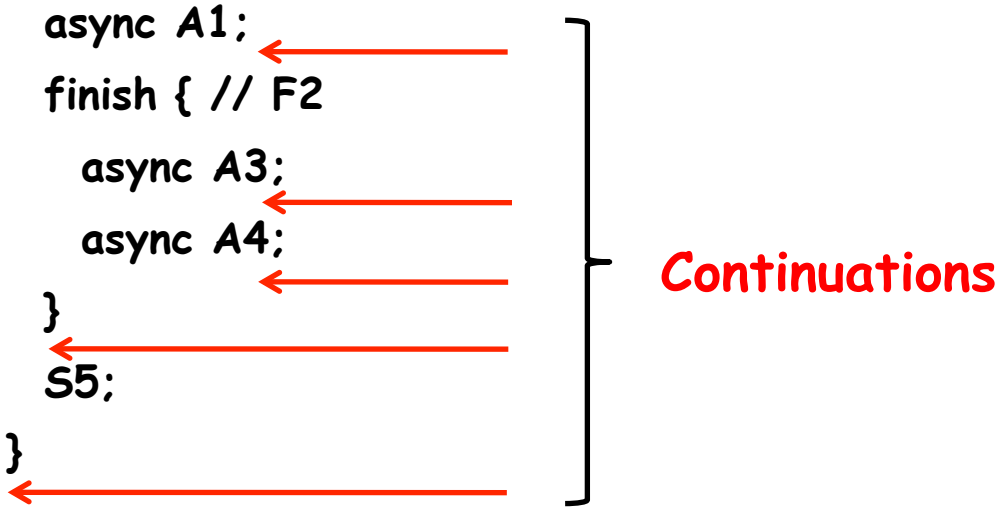


- HJ runtime creates a small number of *worker* threads, typically one per core
- Workers push async's/continuations into a logical *work queue*
  - when an async operation is performed
  - when an end-finish operation is reached
- Workers pull task/continuation work item when they are idle

Continuations

- A continuation is one of two kinds of program points
  - The point in the parent task immediately following an async
  - The point immediately following an end-finish
- Continuations are also referred to as task-switching points
  - Program points at which a worker may switch execution between different tasks

```
finish { // F1
  async A1;
  finish { // F2
    async A3;
    async A4;
  }
  S5;
}
```



Local Variables

- Java variables can be classified as *local* or *shared*
- A local variable is only visible in the scope in which it is defined
- A shared variable (static field, instance field, array element) can potentially be accessed anywhere
- Three rules for accessing local variables across tasks in HJ:

```
// Rule 1: an inner async may access the value of any outer final local var
final int i1 = 1; async { ... = i1; /* i1=1 */ }

// Rule 2: an inner async may access the value of any outer local var
int i2 = 2; // i2=2 is  copied on entry into the async like a method param
async { ... = i2; /* i2=2*/}
i2 = 3; // This assignment is not seen by the above async

// Rule 3: an inner async is not permitted to modify an outer local var
int i3; async { i3 = ...; /* ERROR */}
```


Finish Statements

- Implicit finish statement in main() method
- Each async task has a unique Immediately Enclosing Finish (IEF)
- One possible approach to converting a sequential Java program to a parallel HJ program
  - Insert async's at points where parallelism is desired
  - Then insert finish's to ensure that the parallel version produces the same results as the sequential version

Finish Example #1

```
// Example 1: Sequential version
for (int i = 0; i < a.length; i++) A[i] = B[i] + C[i];
System.out.println(A[0]);

// Example 1: Incorrect parallel version
for (int i = 0; i < a.length; i++) async A[i] = B[i] + C[i];
System.out.println(A[0]);

// Example 1: Correct parallel version
finish for (int i = 0; i < a.length; i++) async A[i] = B[i] + C[i];
System.out.println(A[0]);
```


Finish Example #2

```
// Example 2: Sequential version
p = first;
while ( p != null ) {
  p.x = p.y + p.z;   p = p.next;
} System.out.println(first.x);

// Example 2: Incorrect parallel version
p = first;
while ( p != null ) {
  async { p.x = p.y + p.z; }
  p = p.next;
} System.out.println(first.x);
```


Finish Example #2 (contd)

```
// Example 2: Correct parallel version
p = first;
finish while ( p != null ) {
  async { p.x = p.y + p.z; }
  p = p.next;
}
System.out.println(first.x);
```


Which statements can potentially be executed in parallel with each other?

```
finish { // F1
  // Part 1 of Task A0
  async {A1; async A2;}
  finish { // F2
    // Part 2 of Task A0
    async A3;
    async A4;
  }
  // Part 3 of Task A0
}
```

- Example: A2 can potentially execute in parallel with A3 and A4, but Part 3 of A0 cannot execute in parallel with A3 and A4

Async-Finish Exception Semantics

- Any exception thrown by an async is accumulated into a MultiException at its Immediately Enclosing Finish (IEF)

```
finish { // F1
  // Part 1 of Task A0
  async {A1; async A2;}
  try {
    finish { // F2
      // Part 2 of Task A0
      try { async A3; }
      catch (Exception e1) { }; // will not catch exception in A3
      async A4;
    }
  } catch (Exception e2) { }; // will catch exception in A3
  // Part 3 of Task A0 }
```