How Parallel Programs are Developed in Java (Part 1)

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Learning Objectives in this Part of the Lesson

- Recognize the parallelism frameworks supported by Java, e.g.
  - **Fork-join pools**
    - An object-oriented data parallelism framework

See docs.oracle.com/javase/tutorial/essential/concurrency/forkjoin.html

Overview of Java Object-Oriented Parallelism Frameworks

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- The fork-join framework defines an object-oriented parallelism model

See www.infoq.com/interviews/doug-lea-fork-join

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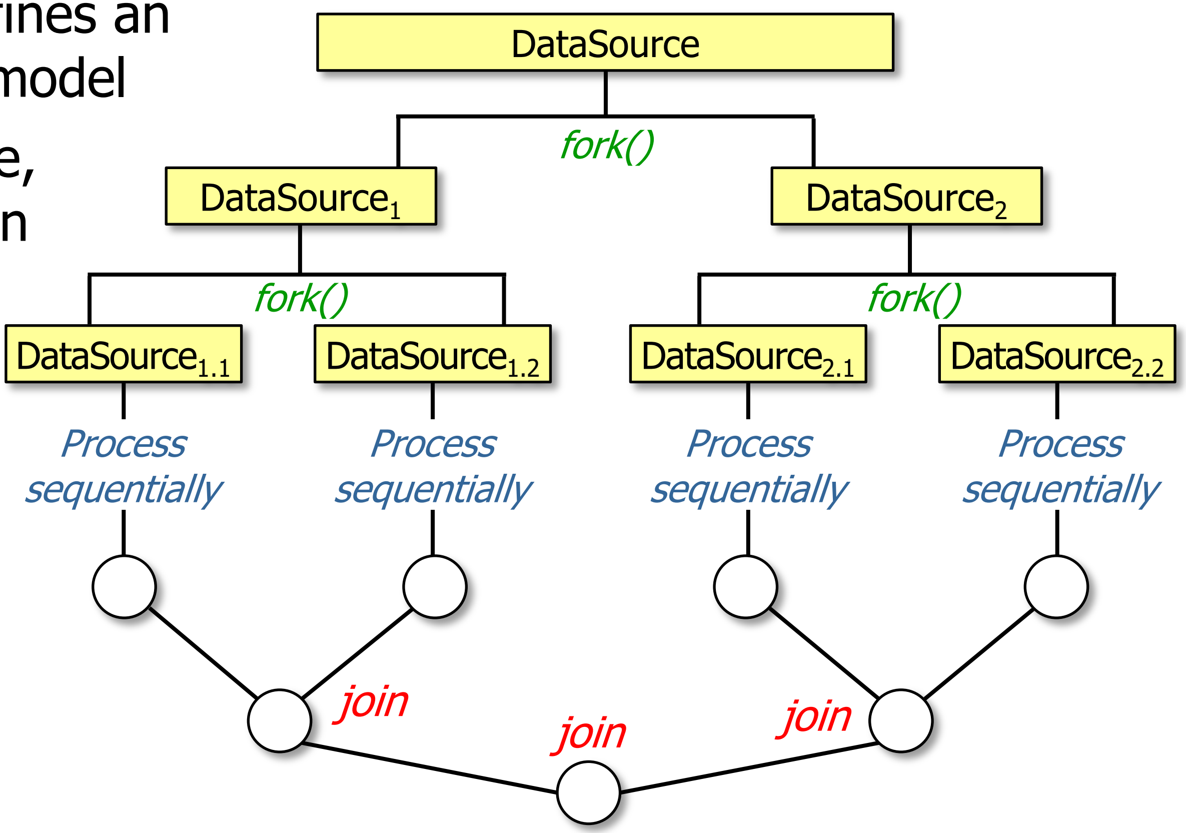
- The fork-join framework defines an object-oriented parallelism model
  - Provides high performance, fine-grained task execution



Designed to scale up to processors with many cores (*cf.* the executor framework)

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  - Provides high performance, fine-grained task execution
  - The focus is on data parallelism
    - i.e., data is partitioned across multiple threads/cores, which operate on the data in parallel

See en.wikipedia.org/wiki/Data_parallelism

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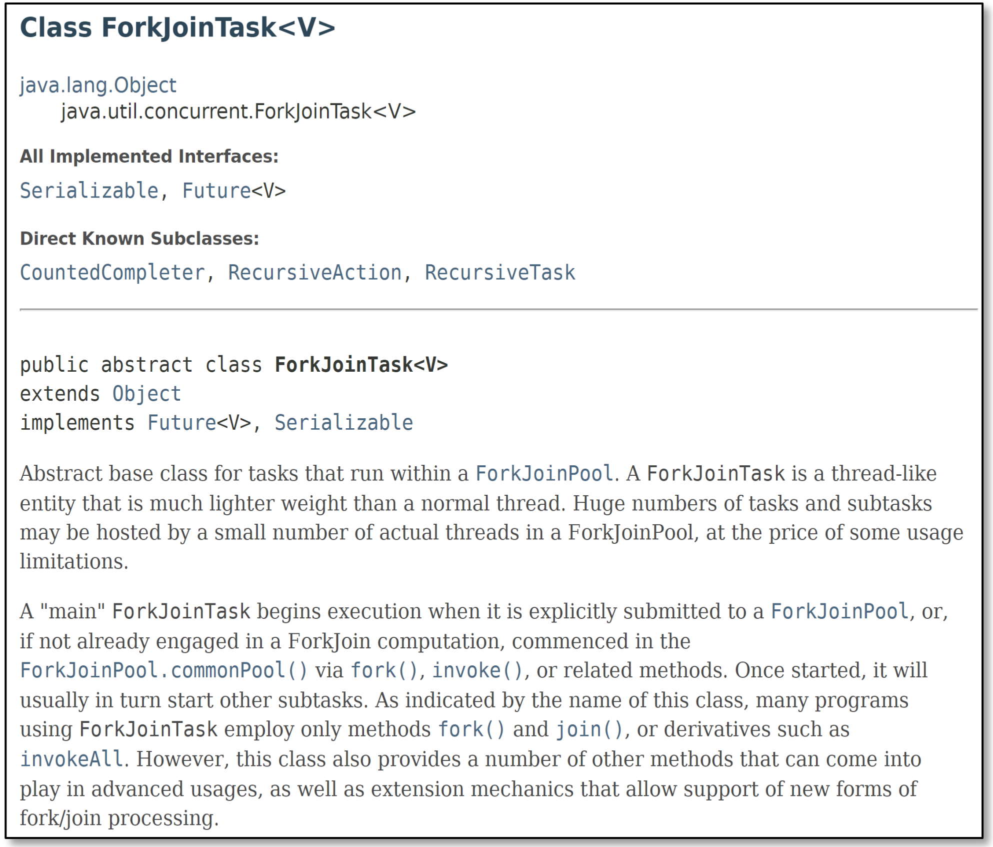

Class ForkJoinTask<V>

java.lang.Object
    java.util.concurrent.ForkJoinTask<V>

All Implemented Interfaces:

`Serializable`, `Future<V>`

Direct Known Subclasses:

`CountedCompleter`, `RecursiveAction`, `RecursiveTask`

```
public abstract class ForkJoinTask<V>
extends Object
implements Future<V>, Serializable
```

Abstract base class for tasks that run within a `ForkJoinPool`. A `ForkJoinTask` is a thread-like entity that is much lighter weight than a normal thread. Huge numbers of tasks and subtasks may be hosted by a small number of actual threads in a ForkJoinPool, at the price of some usage limitations.

A "main" `ForkJoinTask` begins execution when it is explicitly submitted to a `ForkJoinPool`, or, if not already engaged in a ForkJoin computation, commenced in the `ForkJoinPool.commonPool()` via `fork()`, `invoke()`, or related methods. Once started, it will usually in turn start other subtasks. As indicated by the name of this class, many programs using `ForkJoinTask` employ only methods `fork()` and `join()`, or derivatives such as `invokeAll`. However, this class also provides a number of other methods that can come into play in advanced usages, as well as extension mechanics that allow support of new forms of fork/join processing.

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ForkJoinTask.html

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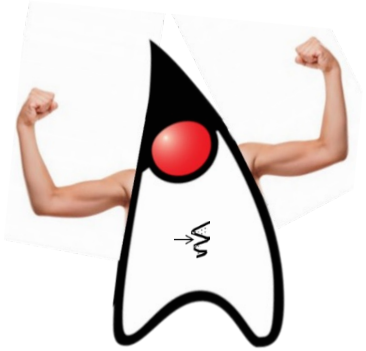
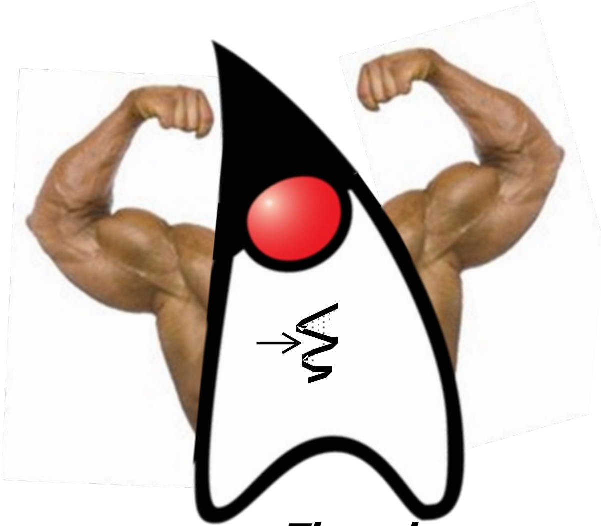
    - A ForkJoinTask is lighter weight than a Java thread





e.g., it doesn't maintain its own run-time stack, registers, thread-local storage, etc.

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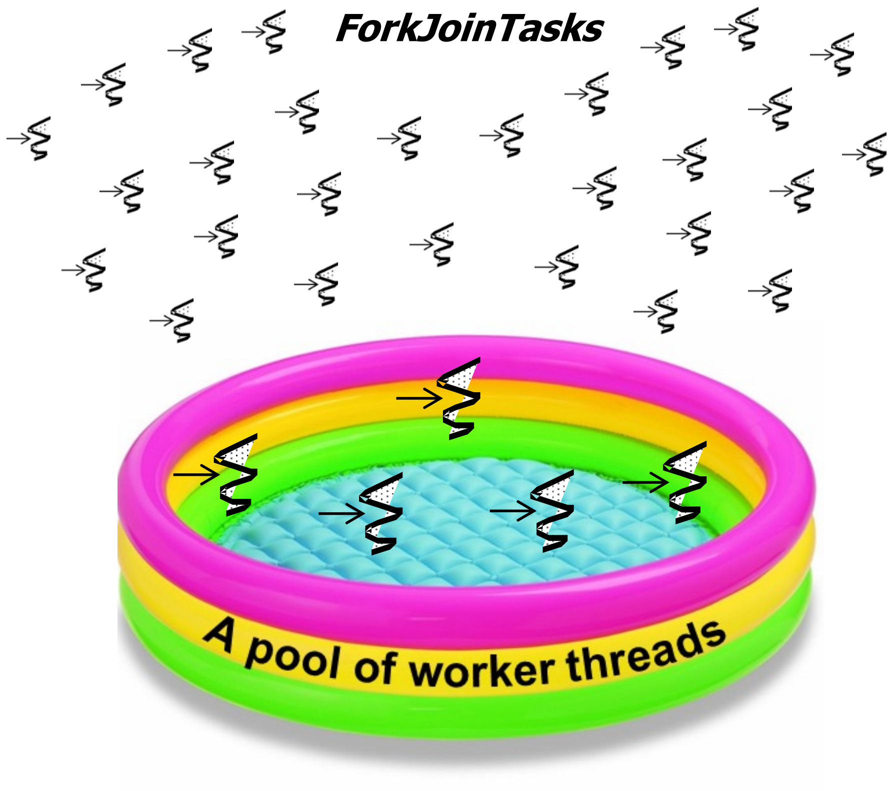
    - A ForkJoinTask is lighter weight than a Java thread
    - A large # of ForkJoinTasks can thus run in a small # of worker threads in a fork-join pool



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  - Supports parallel programming by solving problems via "divide & conquer"

```
solve(Problem problem) {
  if (problem is small)
    directly solve problem
  else {
    a. split problem into
       independent parts
    b. fork new sub-tasks
       to solve each part
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    d. compose result
       from sub-results
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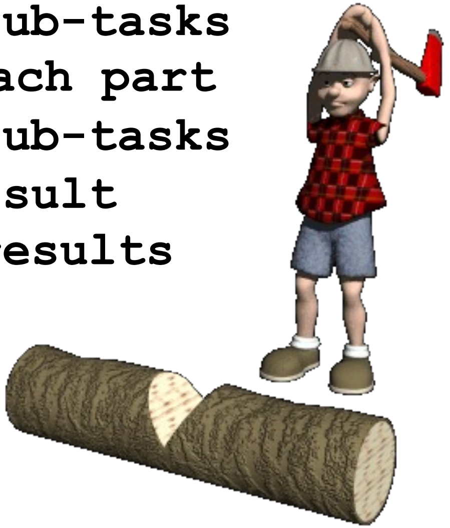

See en.wikipedia.org/wiki/Divide_and_conquer_algorithm

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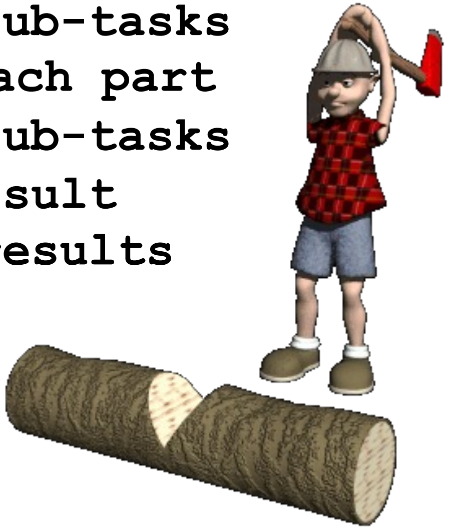

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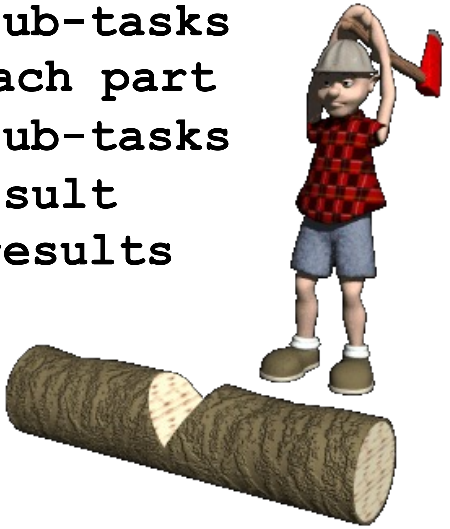

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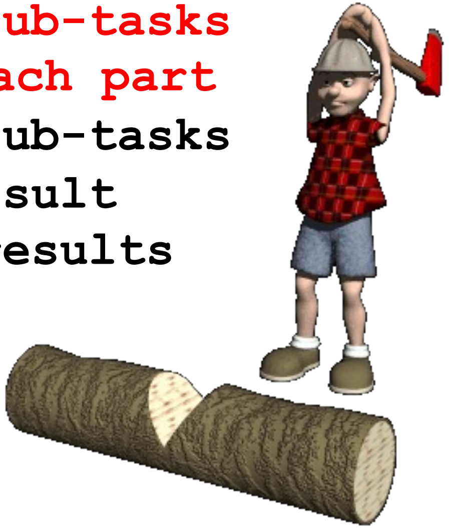

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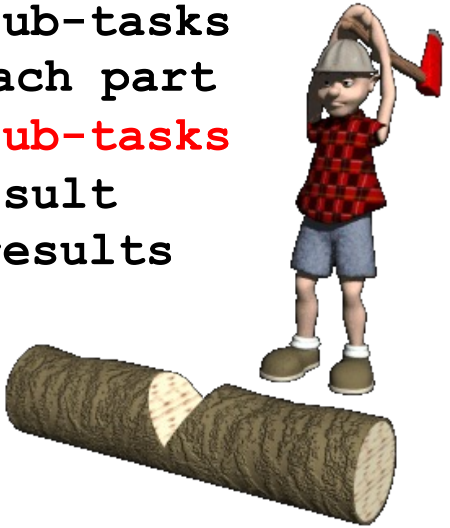

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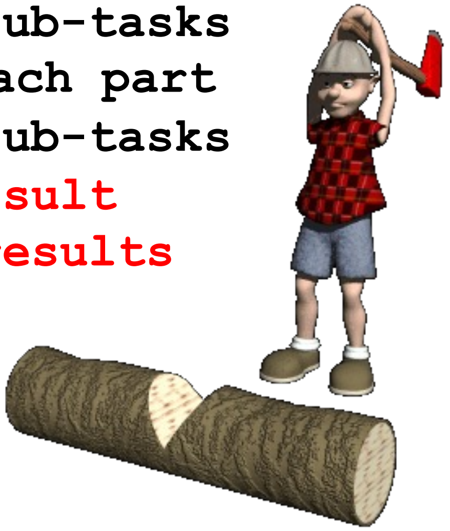

Evaluating the Pros & Cons of the Fork-Join Framework

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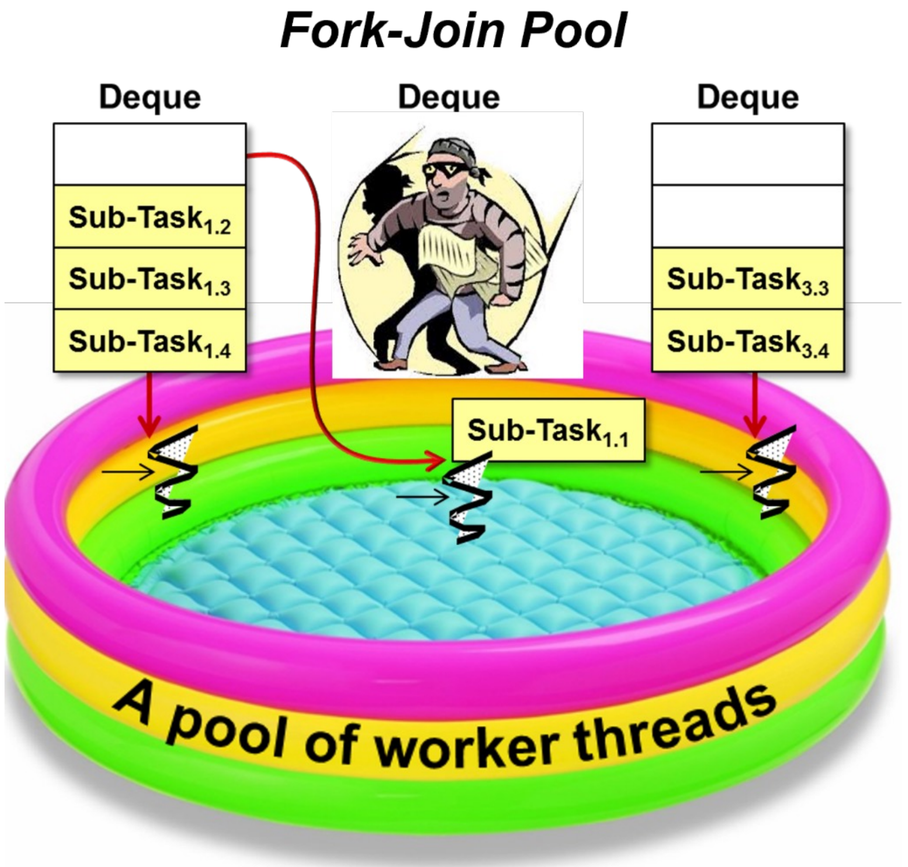
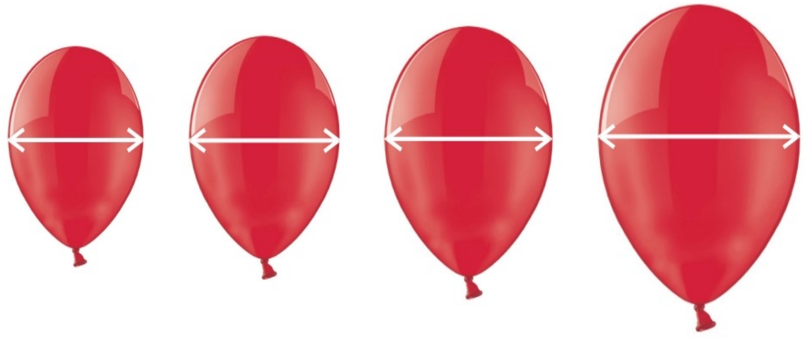
  - Employs *work-stealing* to maximize multi-core processor utilization

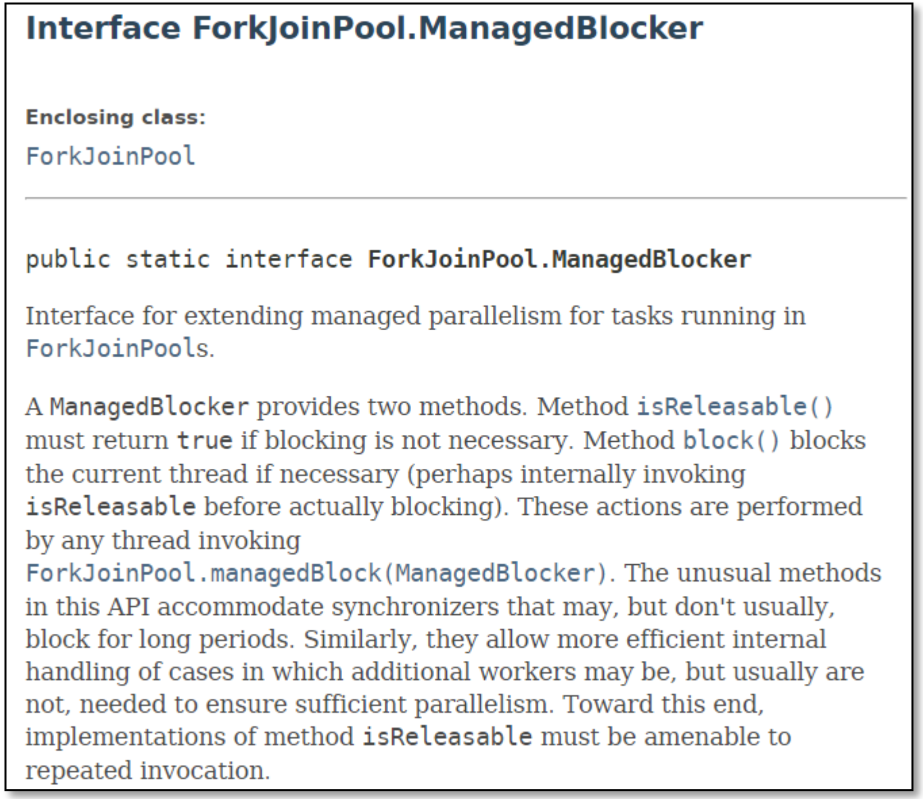


See gee.cs.oswego.edu/dl/papers/fj.pdf

Evaluating the Pros & Cons of the Fork-Join Framework

- Pros of the fork-join framework
  - Employs *work-stealing* to maximize multi-core processor utilization
  - The common fork-join pool size can be expanded automatically via the ManagedBlocker mechanism





Interface ForkJoinPool.ManagedBlocker

Enclosing class:

`ForkJoinPool`

```
public static interface ForkJoinPool.ManagedBlocker
```

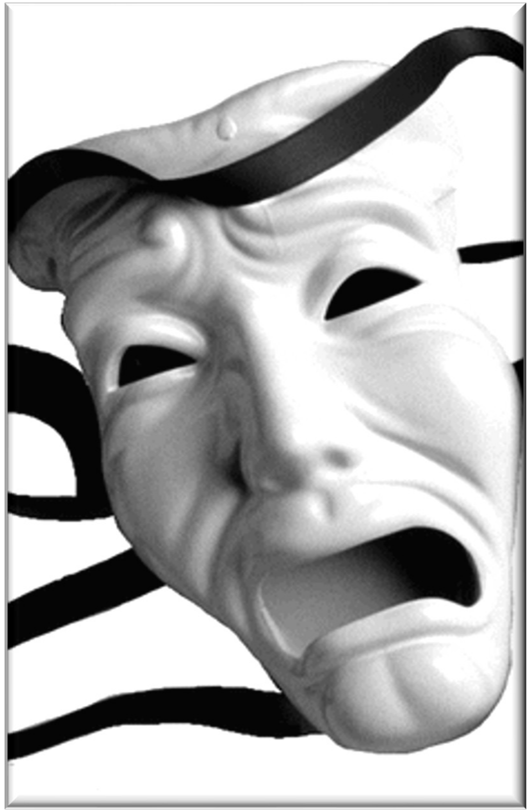
Interface for extending managed parallelism for tasks running in `ForkJoinPool`s.

A `ManagedBlocker` provides two methods. Method `isReleasable()` must return `true` if blocking is not necessary. Method `block()` blocks the current thread if necessary (perhaps internally invoking `isReleasable` before actually blocking). These actions are performed by any thread invoking `ForkJoinPool.managedBlock(ManagedBlocker)`. The unusual methods in this API accommodate synchronizers that may, but don't usually, block for long periods. Similarly, they allow more efficient internal handling of cases in which additional workers may be, but usually are not, needed to ensure sufficient parallelism. Toward this end, implementations of method `isReleasable` must be amenable to repeated invocation.

See docs.oracle.com/javase/8/docs/api/java/util/concurrent/ForkJoinPool.ManagedBlocker.html

Evaluating the Pros & Cons of the Fork-Join Framework

- Cons of the fork-join framework



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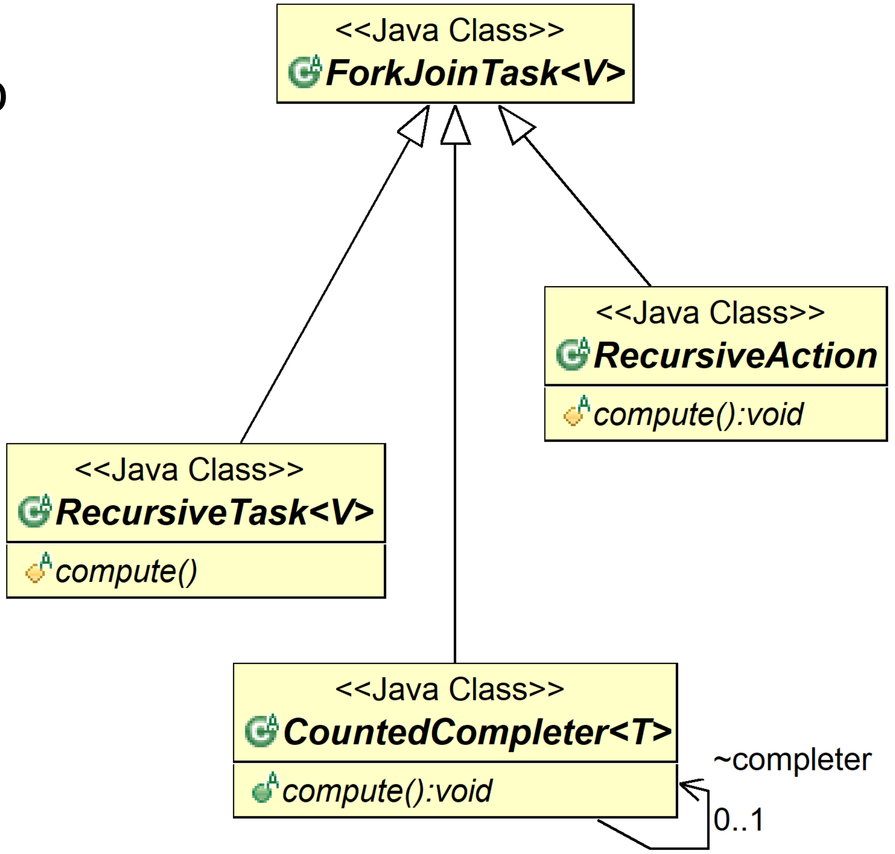

See www.laputan.org/drc.html

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- Cons of the fork-join framework
  - It can be tedious & error-prone to program, e.g.,
    - It uses a “white-box” object-oriented design based on inheritance
      - It’s thus not integrated with modern Java’s functional programming features

See docs.oracle.com/javase/tutorial/java/javaOO/lambdaexpressions.html

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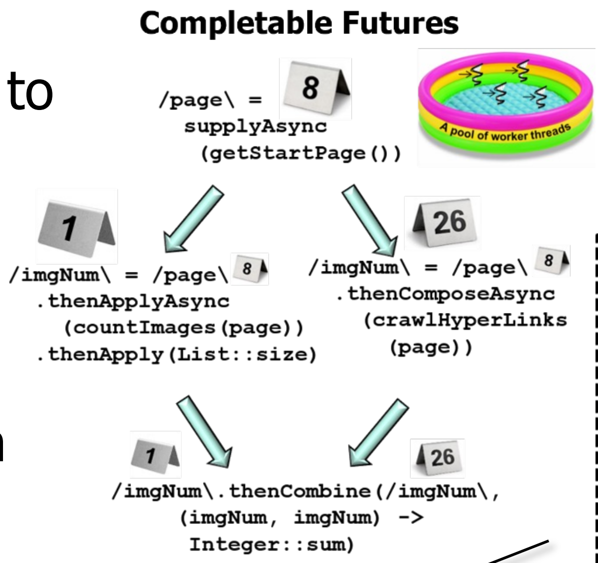
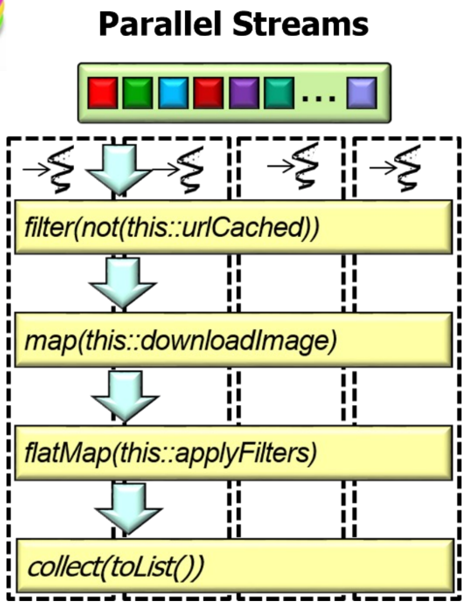

Completable Futures
A pool of worker threads
8
1
26
/page\ = supplyAsync (getStartPage())
/imgNum\ = /page\ .thenApplyAsync (countImages(page)) .thenApply(List::size)
/imgNum\ = /page\ .thenComposeAsync (crawlHyperLinks (page))
/imgNum\.thenCombine(/imgNum\, (imgNum, imgNum) -> Integer::sum)



Overcoming these 'cons' motivates Java's parallel functional programming frameworks, both of which encapsulate the Java fork-join framework

End of How Parallel Programs Are Developed in Java (Part 1)