How Parallel Programs are Developed in Java (Part 2)

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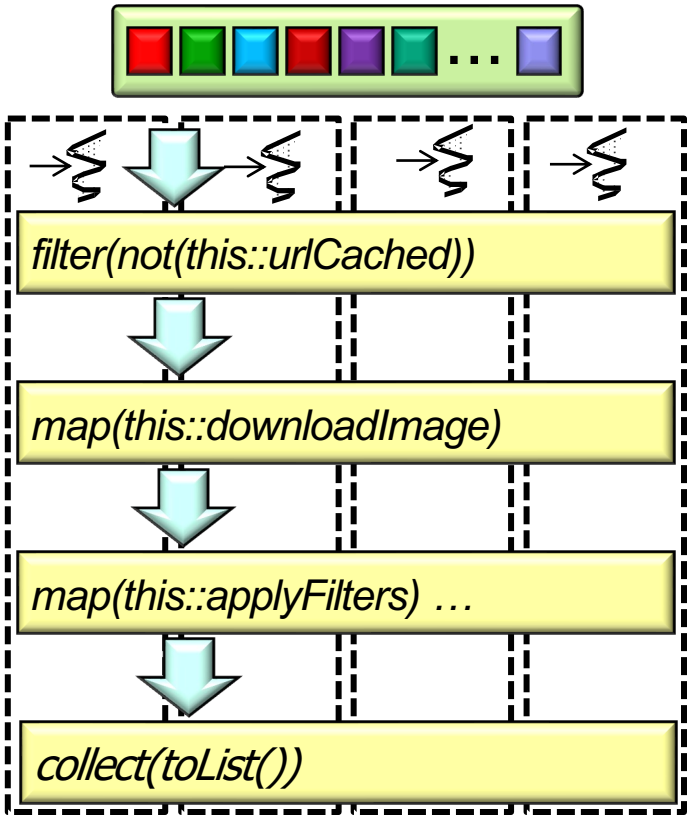
Learning Objectives in this Part of the Lesson

- Recognize the parallelism frameworks supported by Java, e.g.
  - Fork-join pools
  - **Parallel streams**
    - A synchronous parallel functional programming framework



See docs.oracle.com/javase/tutorial/collections/streams/parallelism.html

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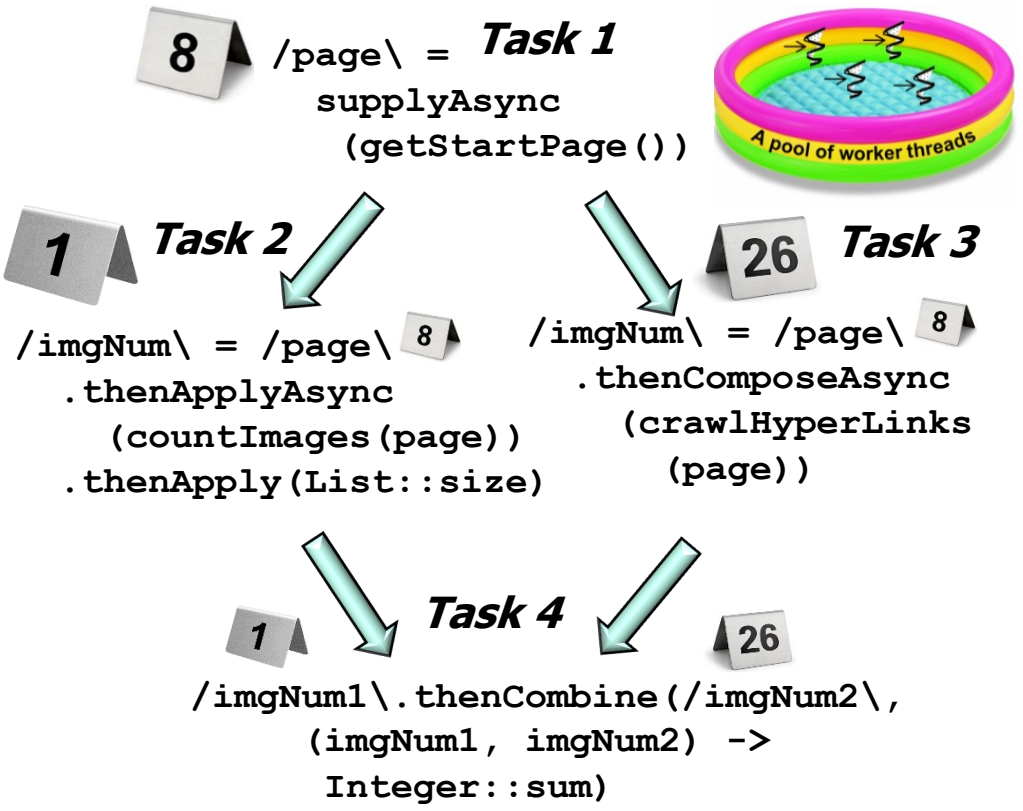

See www.callicoder.com/java-8-completablefuture-tutorial

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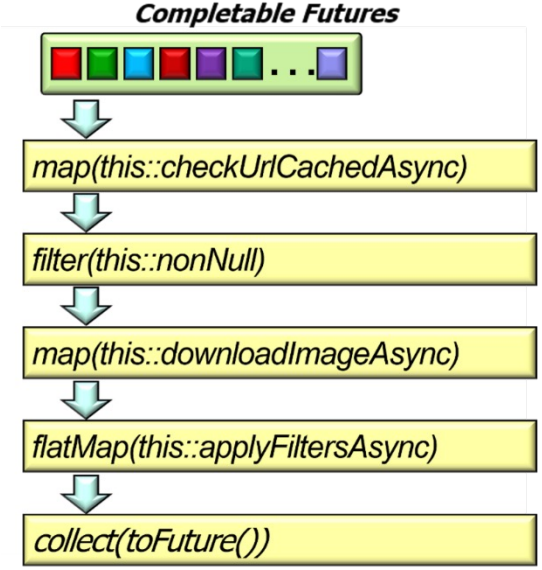
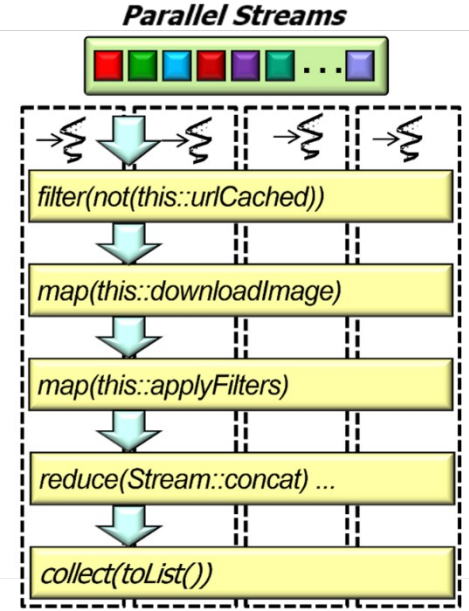




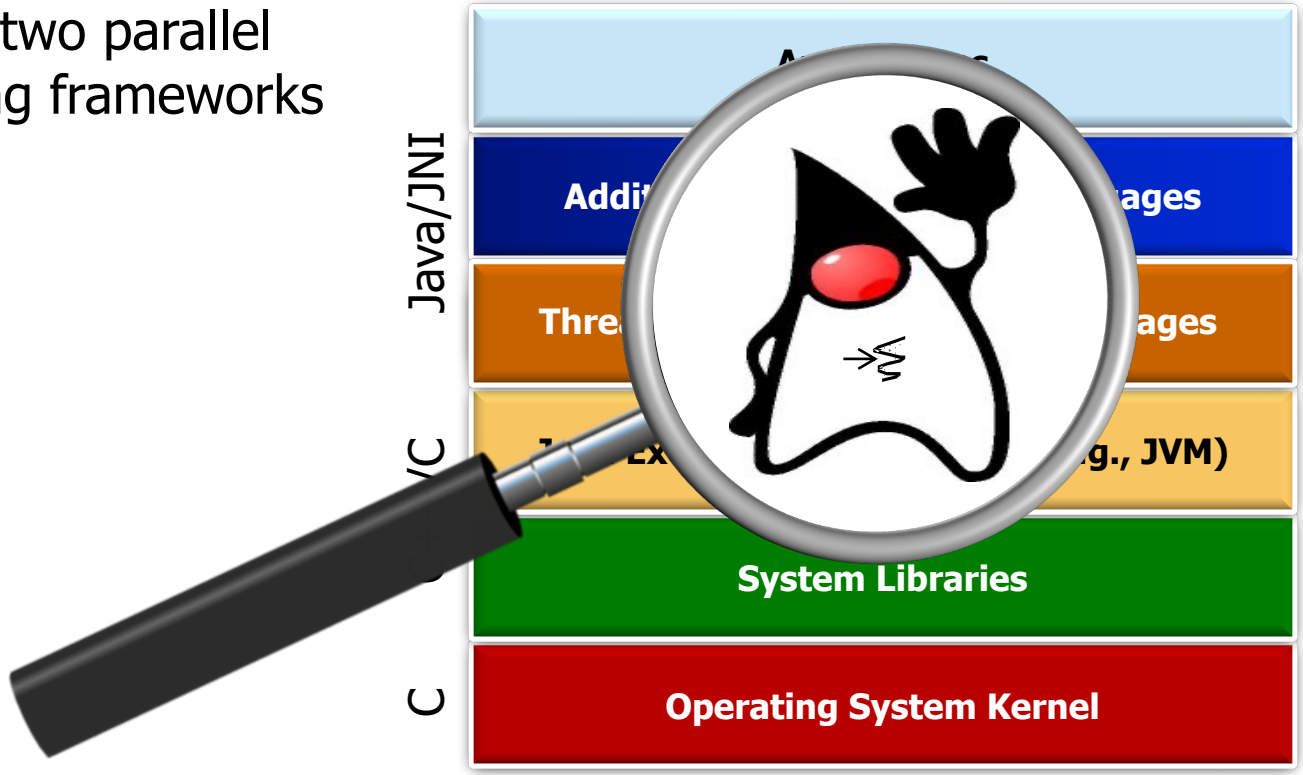
These parallel functional programming frameworks leverage the object-oriented fork-join pool framework by default

See previous lesson on "*How Parallel Programs are Developed in Java (Part 1)*"

Overview of Parallel Functional Programming Frameworks

Overview of Parallel Functional Programming Frameworks

- Modern Java provides two parallel functional programming frameworks



See www.ibm.com/developerworks/library/j-jvmc2

Overview of Parallel Functional Programming Frameworks

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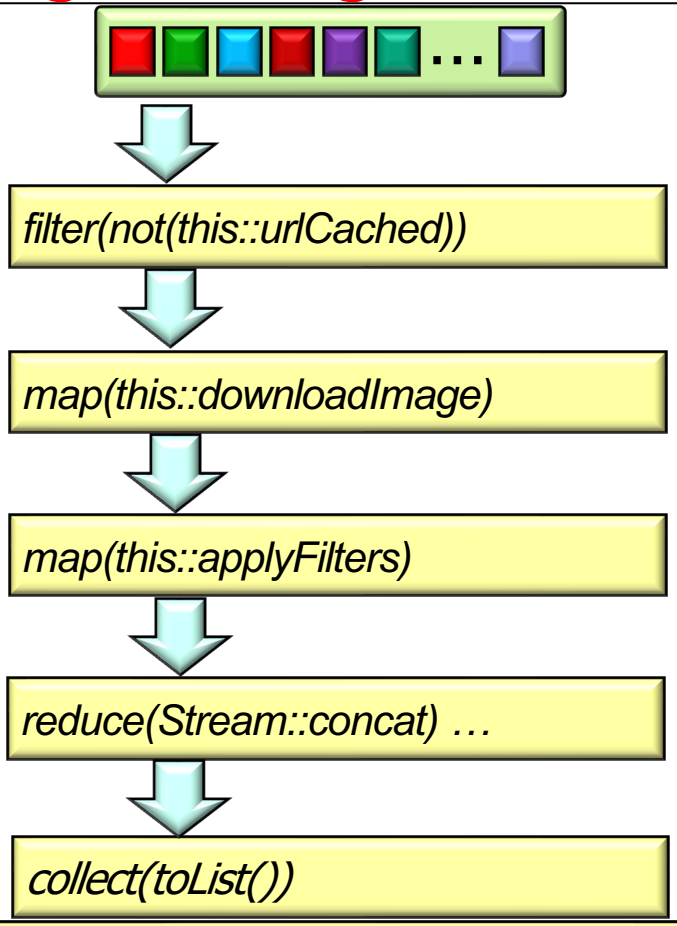

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Overview of Parallel Functional Programming Frameworks

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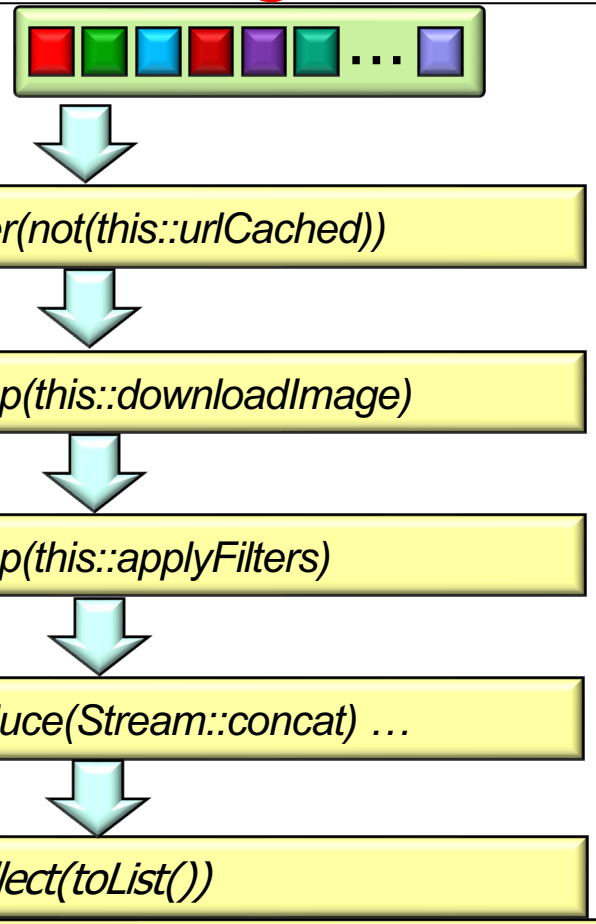
  1. Parallel streams

Process a list of URLs to images that aren't already cached by downloading, transforming, & storing these images in parallel



See github.com/douglascraigschmidt/LiveLessons/tree/master/ImageStreamGang

Overview of Parallel Functional Programming Frameworks

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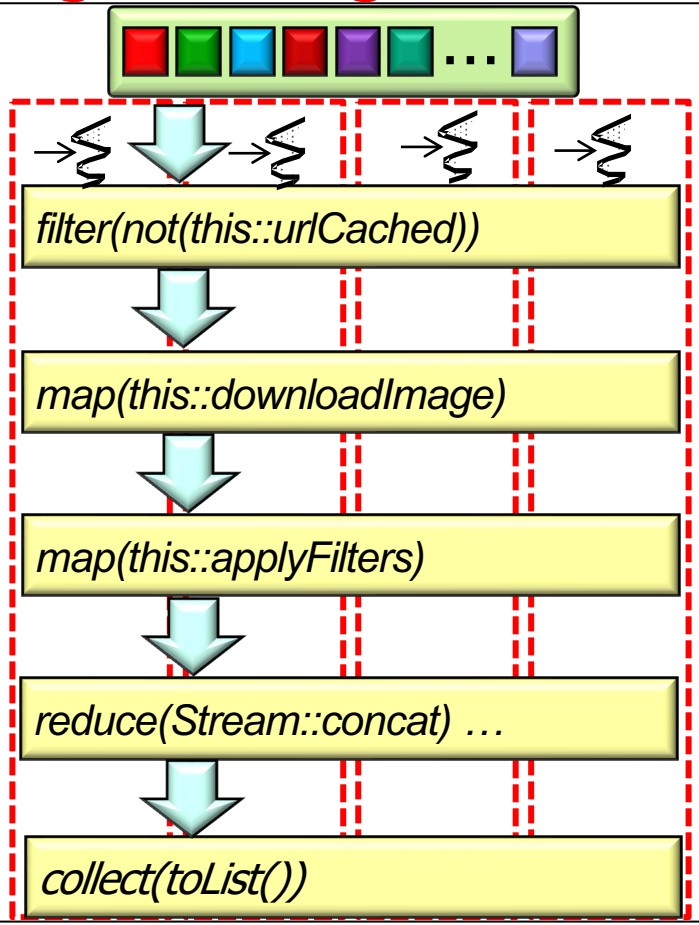
  1. Parallel streams

  - Partitions a stream into multiple ”chunks” that run independently & combine into a “reduced” result



Overview of Parallel Functional Programming Frameworks

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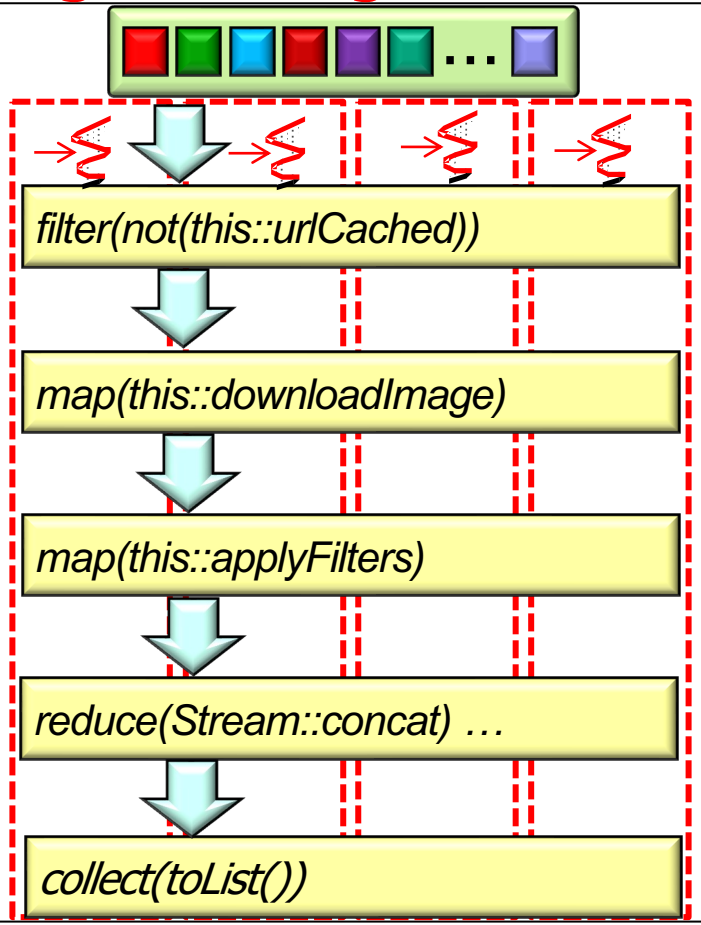
  - These chunks of data are mapped to multiple threads (& cores) & thus processed in parallel



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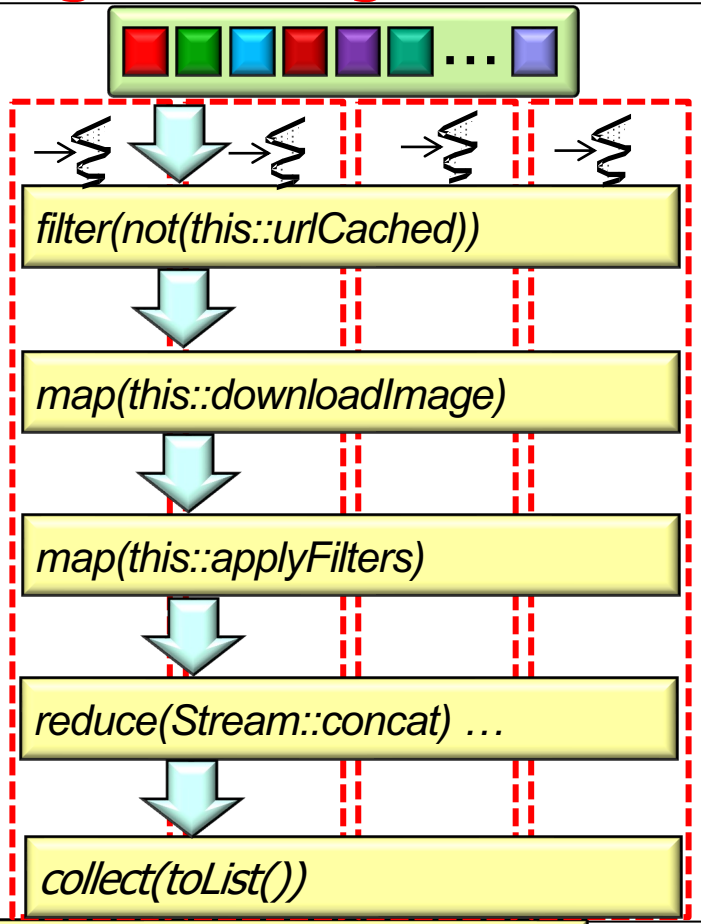

See dzone.com/articles/common-fork-join-pool-and-streams

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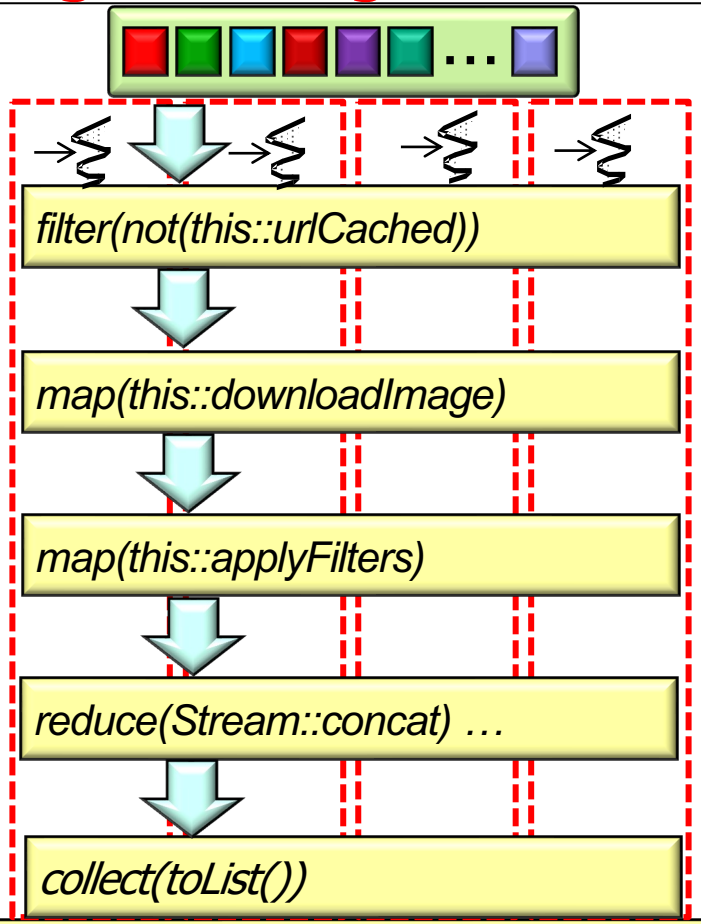
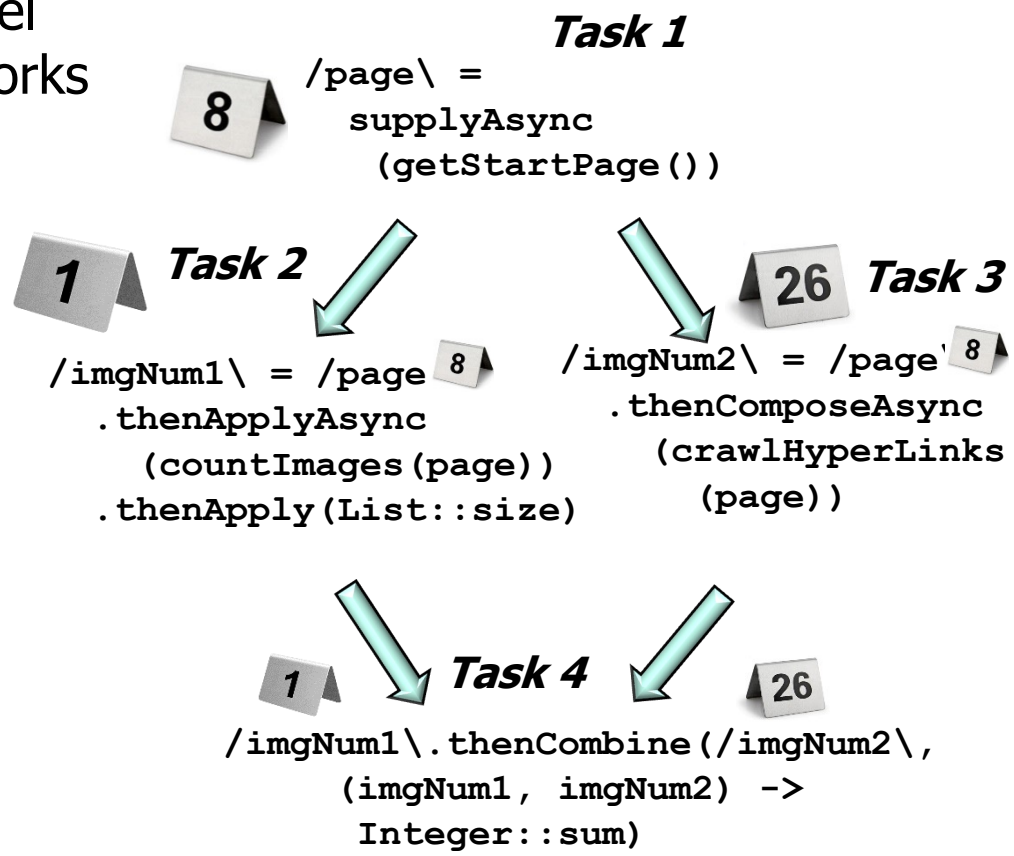


Parallel streams provide fine-grained data parallelism functional programming

Overview of Parallel Functional Programming Frameworks

- Modern Java provides two parallel functional programming frameworks
  1. Parallel streams
  2. **Completable futures**



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

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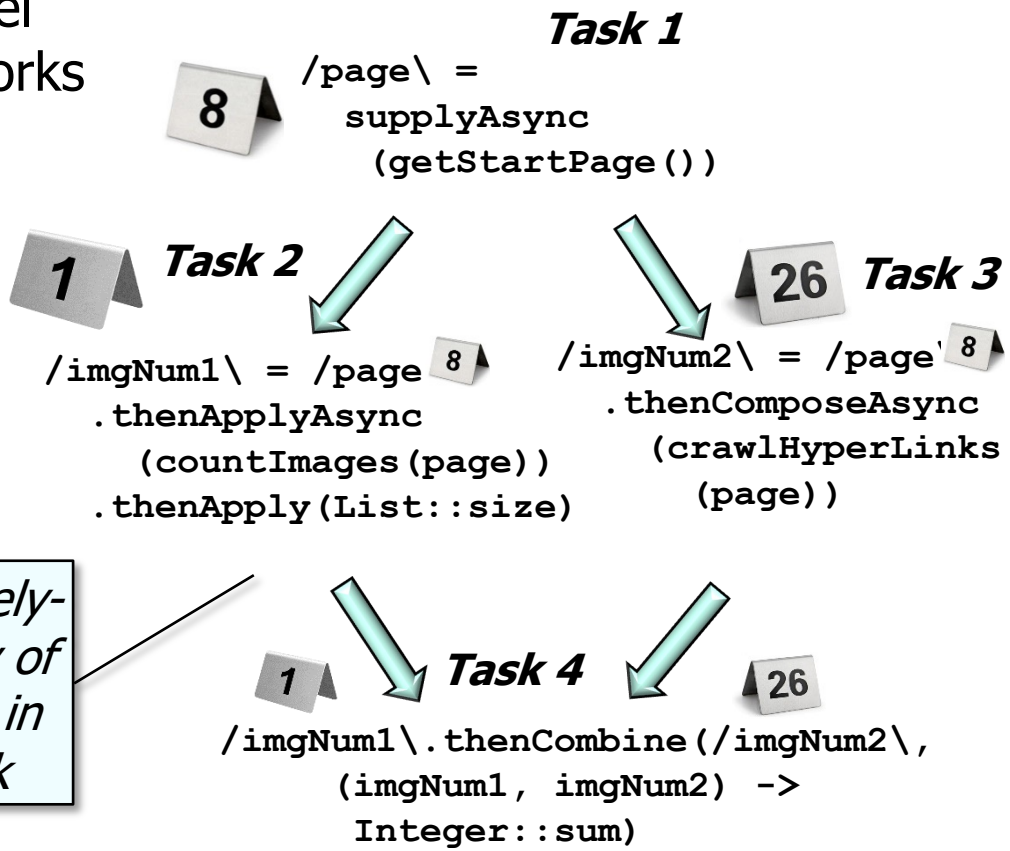

Count the # of images in a recursively-defined folder structure using many of the asynchronous features defined in the completable future framework

See github.com/douglascraigschmidt/LiveLessons/tree/master/ImageCounter

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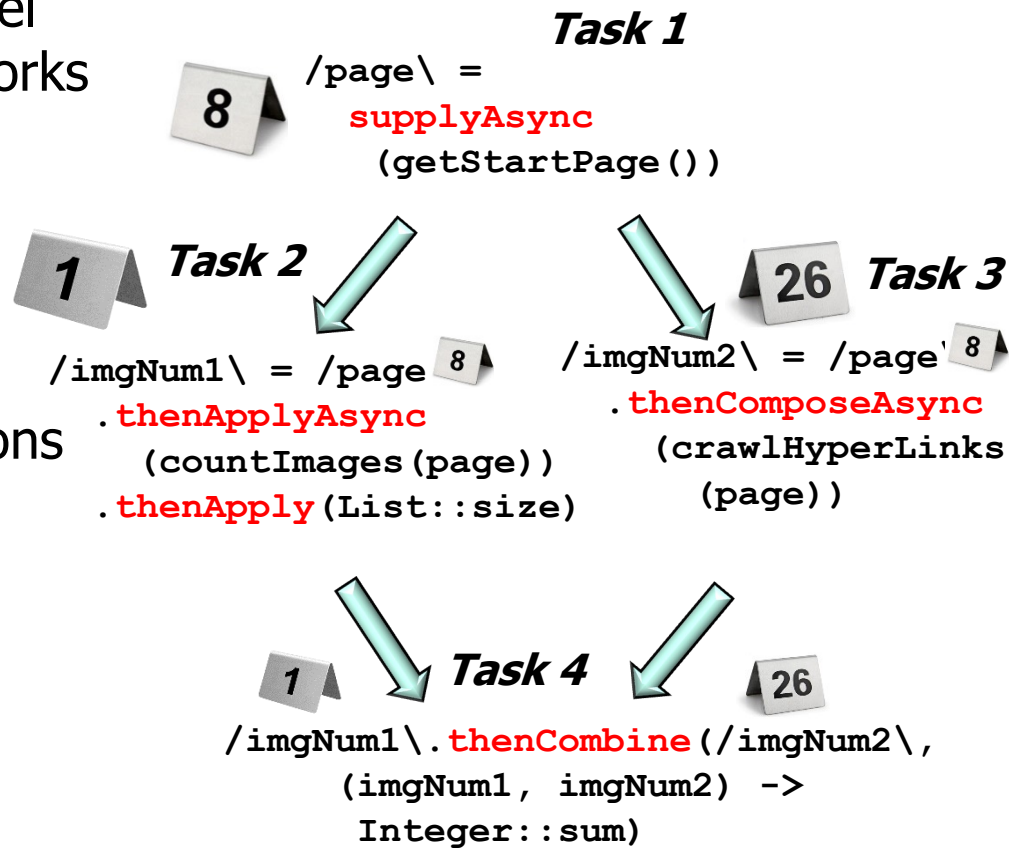
     - Supports dependent actions that are triggered upon the completion of async operations



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

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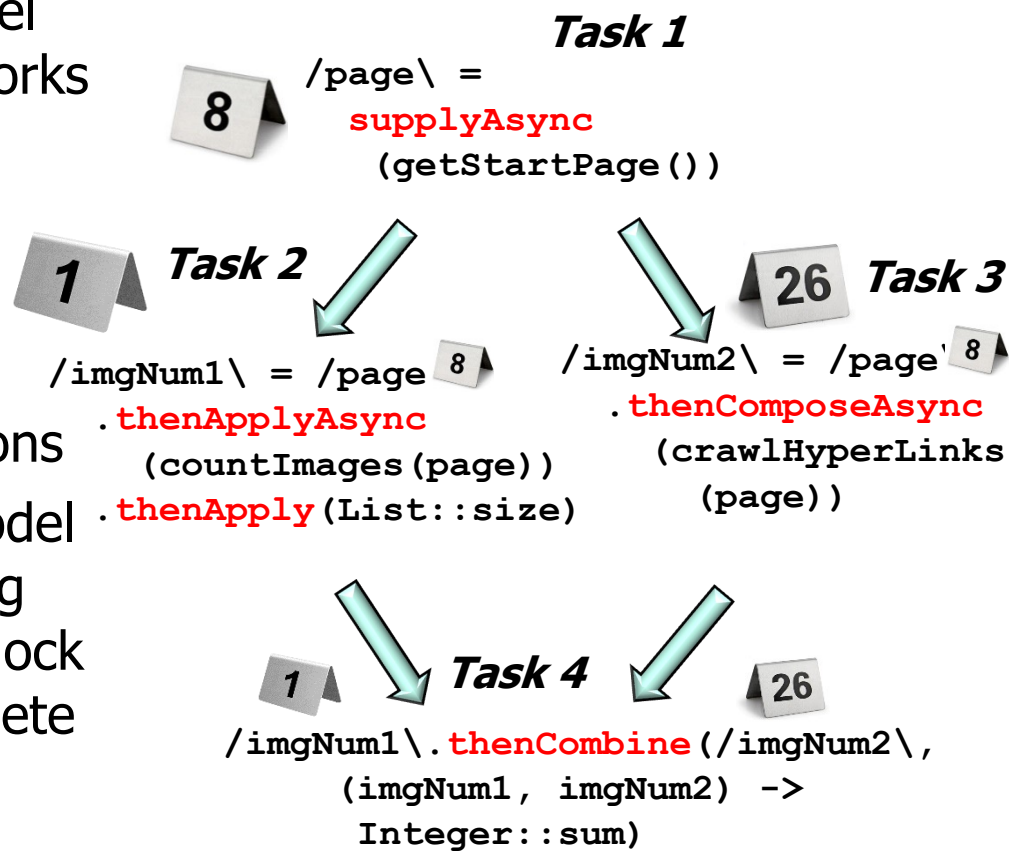
     - Supports dependent actions that are triggered upon the completion of async operations
       - Async operations are a model of concurrent programming where the caller doesn't block waiting for callee to complete



See en.wikipedia.org/wiki/Asynchrony_(computer_programming)

Overview of Parallel Functional Programming Frameworks

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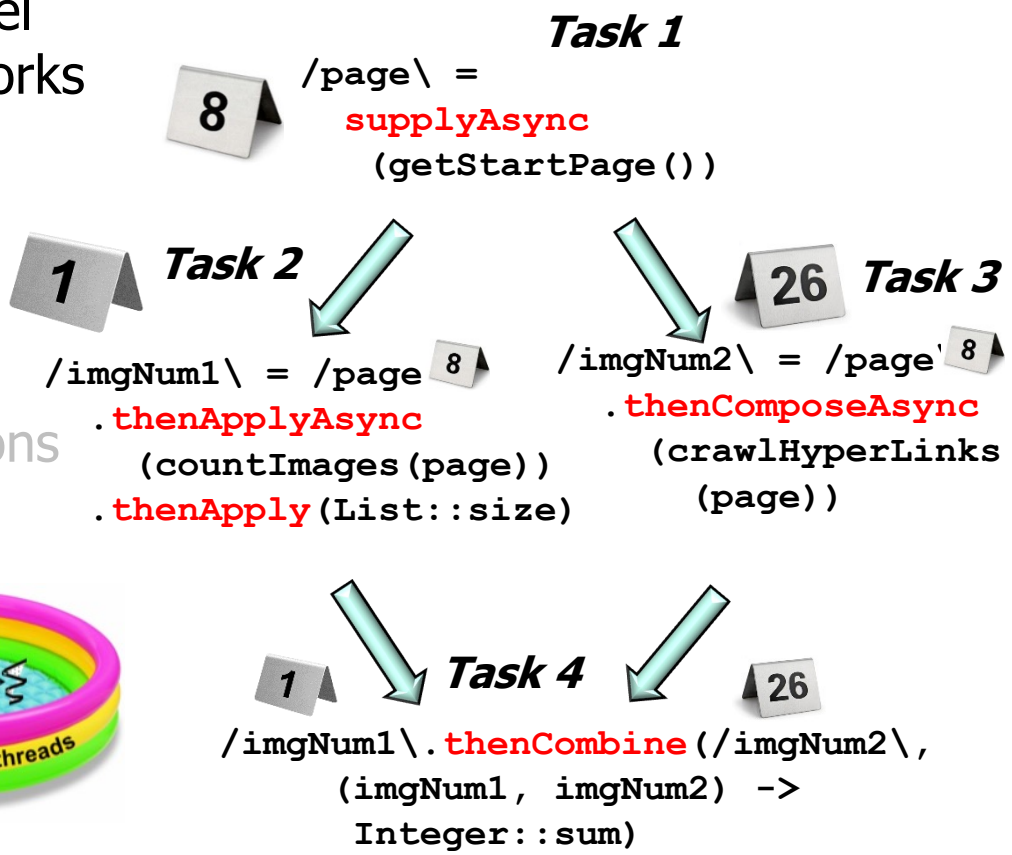
  2. **Completable futures**
     - Supports dependent actions that are triggered upon the completion of async operations
     - Can also leverage the Java common fork-join pool



See www.baeldung.com/java-completablefuture

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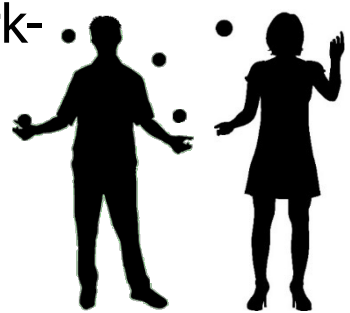

Task 1

8

```
/page\ =
  supplyAsync
   (getStartPage())
```

Task 2

1

```
/imgNum1\ = /page
  .thenApplyAsync
    (countImages(page))
  .thenApply(List::size)
```

Task 3

26

```
/imgNum2\ = /page
  .thenComposeAsync
    (crawlHyperLinks
      (page))
```

Task 4

1 26

```
/imgNum1\.thenCombine(/imgNum2\,
    (imgNum1, imgNum2) ->
     Integer::sum)
```

The completable futures framework supports asynchronous parallel programming

Evaluating Pros & Cons of Parallel Functional Programming Frameworks

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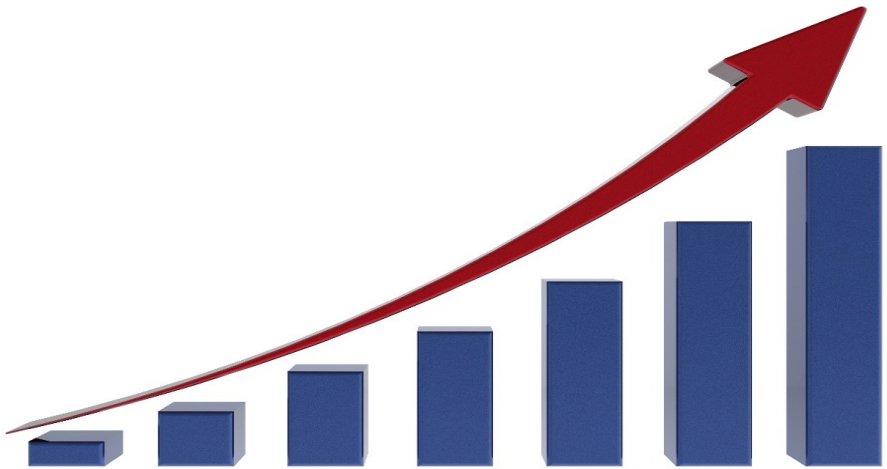
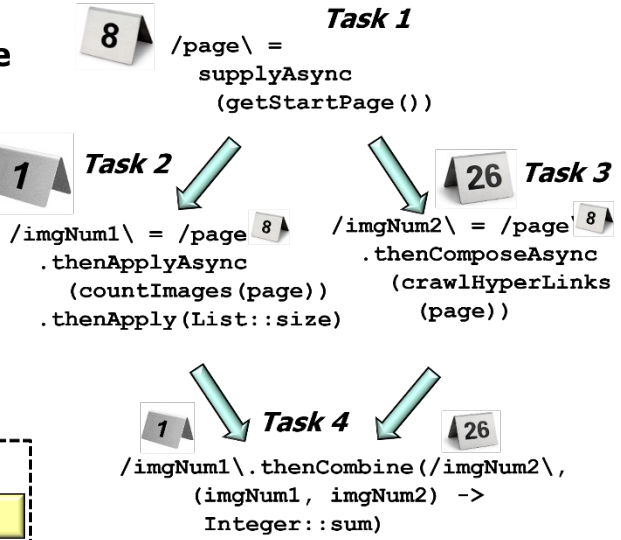
- Pros of the parallel functional programming frameworks
  - These frameworks perform well on modern multi-core processors, while also enhancing productivity



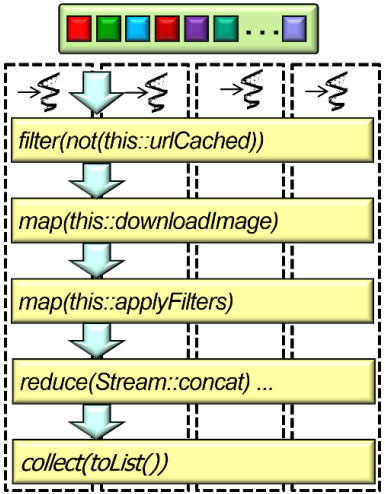
Evaluating Pros & Cons of Parallel Functional Programming Frameworks

- Pros of the parallel functional programming frameworks
  - These frameworks perform well on modern multi-core processors, while also enhancing productivity
    - e.g., they encapsulate the object-oriented fork-join framework with parallel functional programming façades

Completable Futuresa



Parallel Streams



ForkJoinPool

See en.wikipedia.org/wiki/Facade_pattern

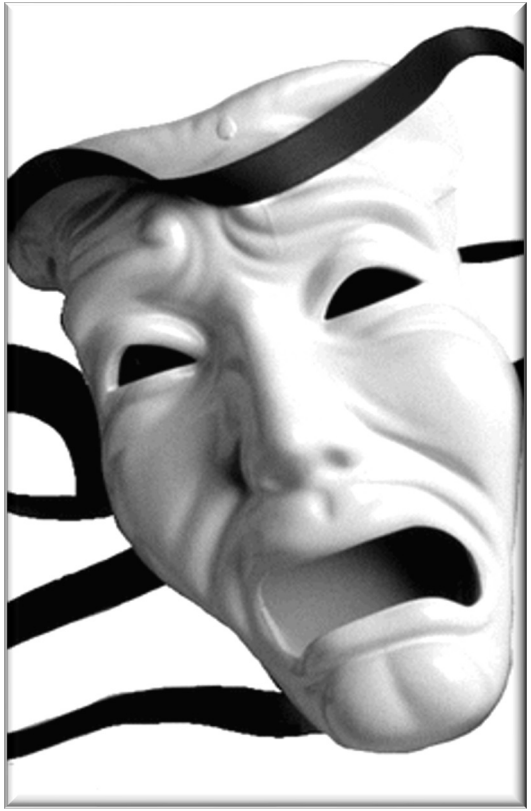
Evaluating Pros & Cons of Parallel Functional Programming Frameworks

- Pros of the parallel functional programming frameworks
  - These frameworks perform well on modern multi-core processors, while also enhancing productivity
  - Explicit synchronization and/or threading is rarely needed when applying these frameworks

Alleviates many accidental & inherent complexities of concurrency/parallelism

Evaluating Pros & Cons of Parallel Functional Programming Frameworks

- Cons of the parallel functional programming frameworks



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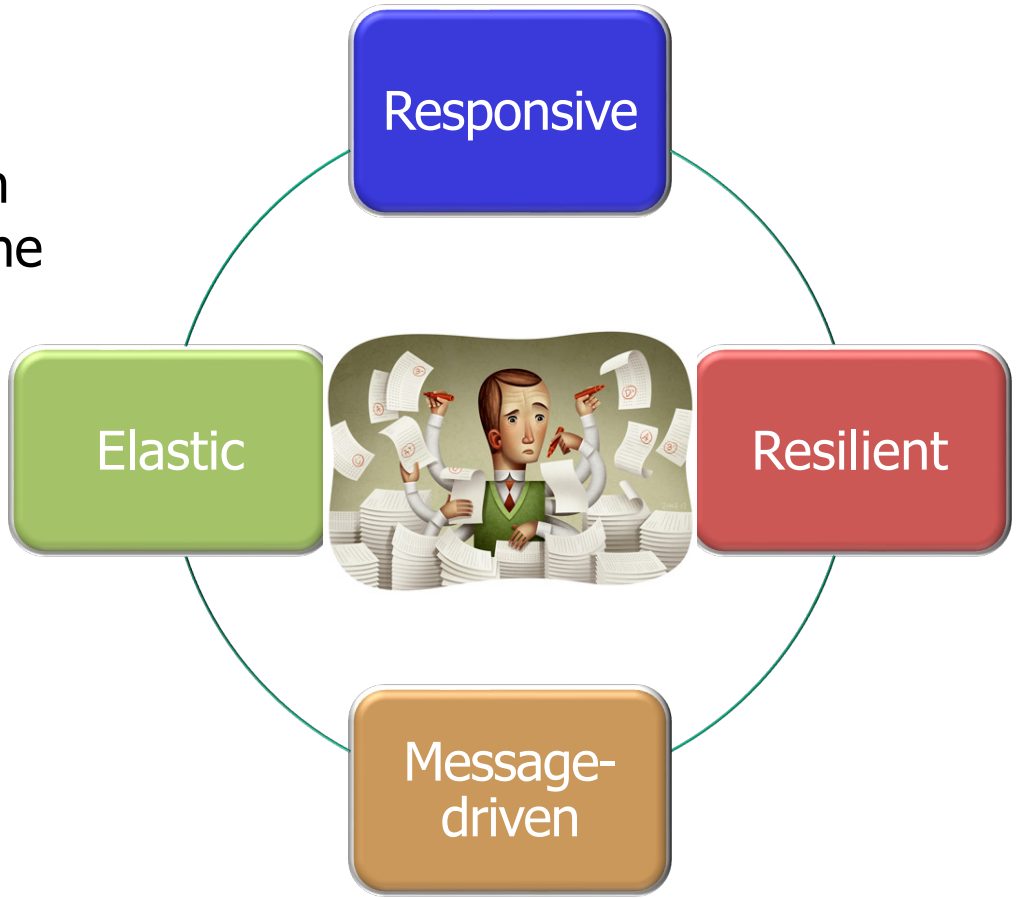
  - Don't fully integrate streams with asynchrony to achieve goals of the reactive programming paradigm



See www.reactivemanifesto.org

Evaluating Pros & Cons of Parallel Functional Programming Frameworks

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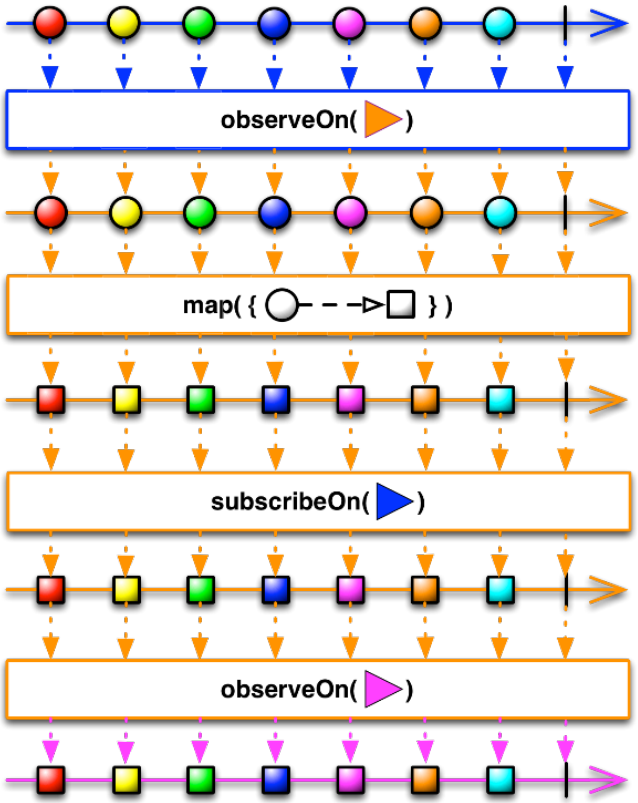
Motivates the need for Java reactive streams frameworks, which integrate streams & asynchrony more intentionally

Project Reactor



See www.reactive-streams.org, www.baeldung.com/rx-java, & projectreactor.io

End of How Parallel Programs Are Developed in Java (Part 2)