How Parallel Programs are Developed in Java (Part 2)

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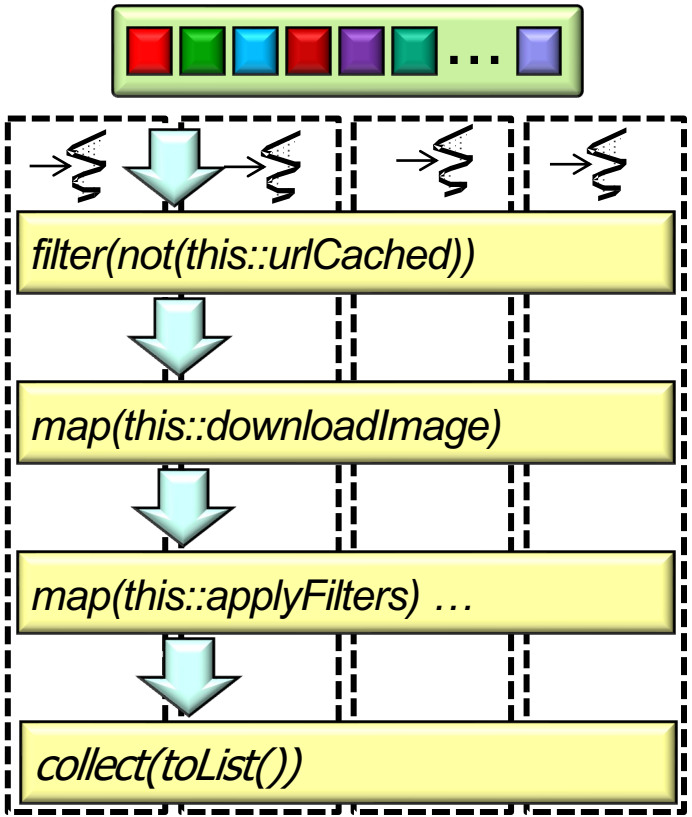
Learning Objectives in this Part of the Lesson

- 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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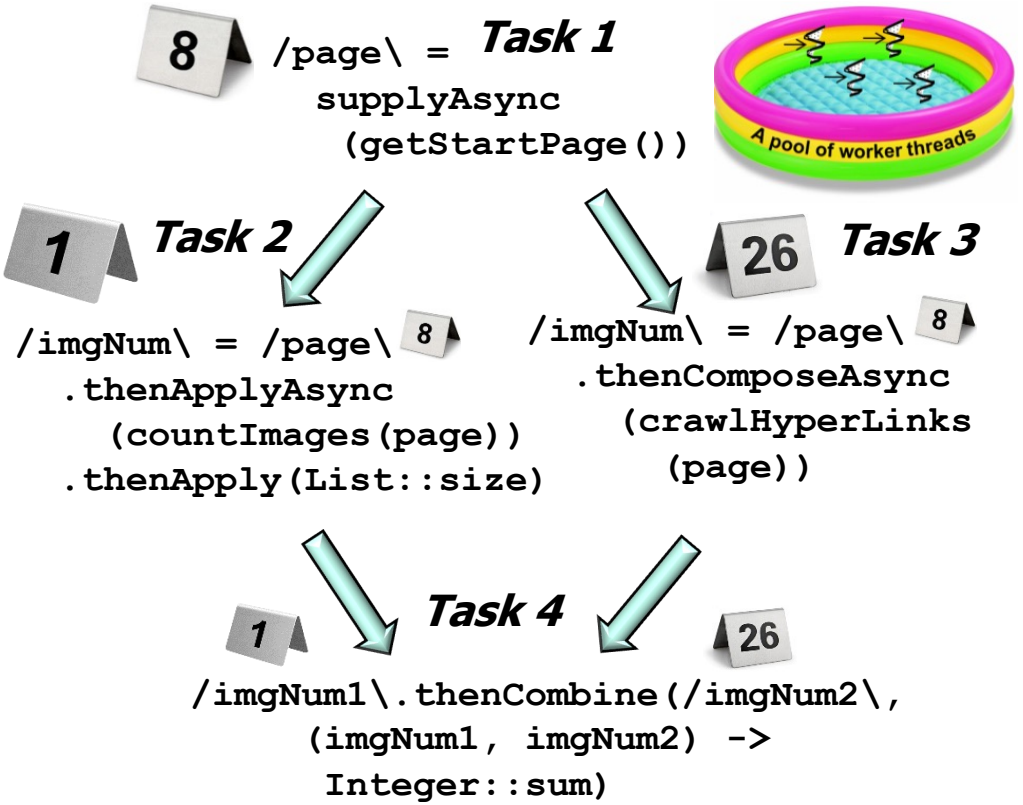

See www.callicoder.com/java-8-completablefuture-tutorial

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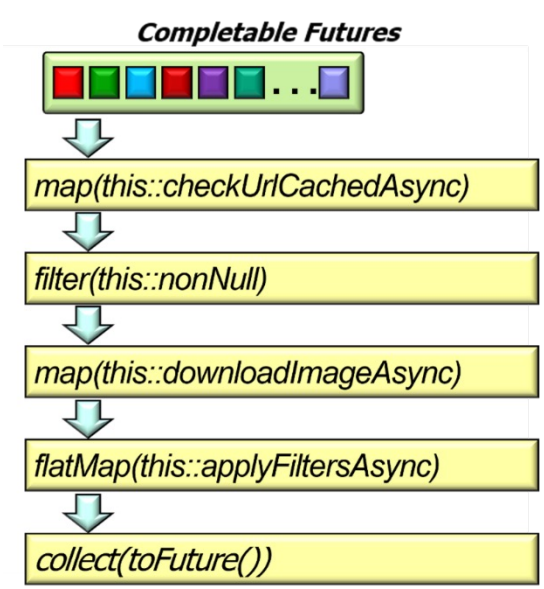
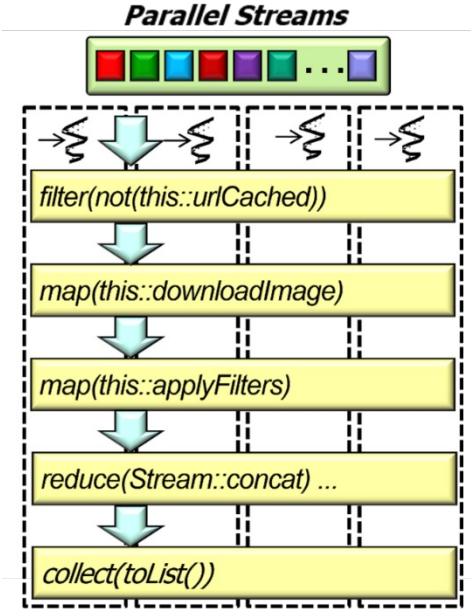




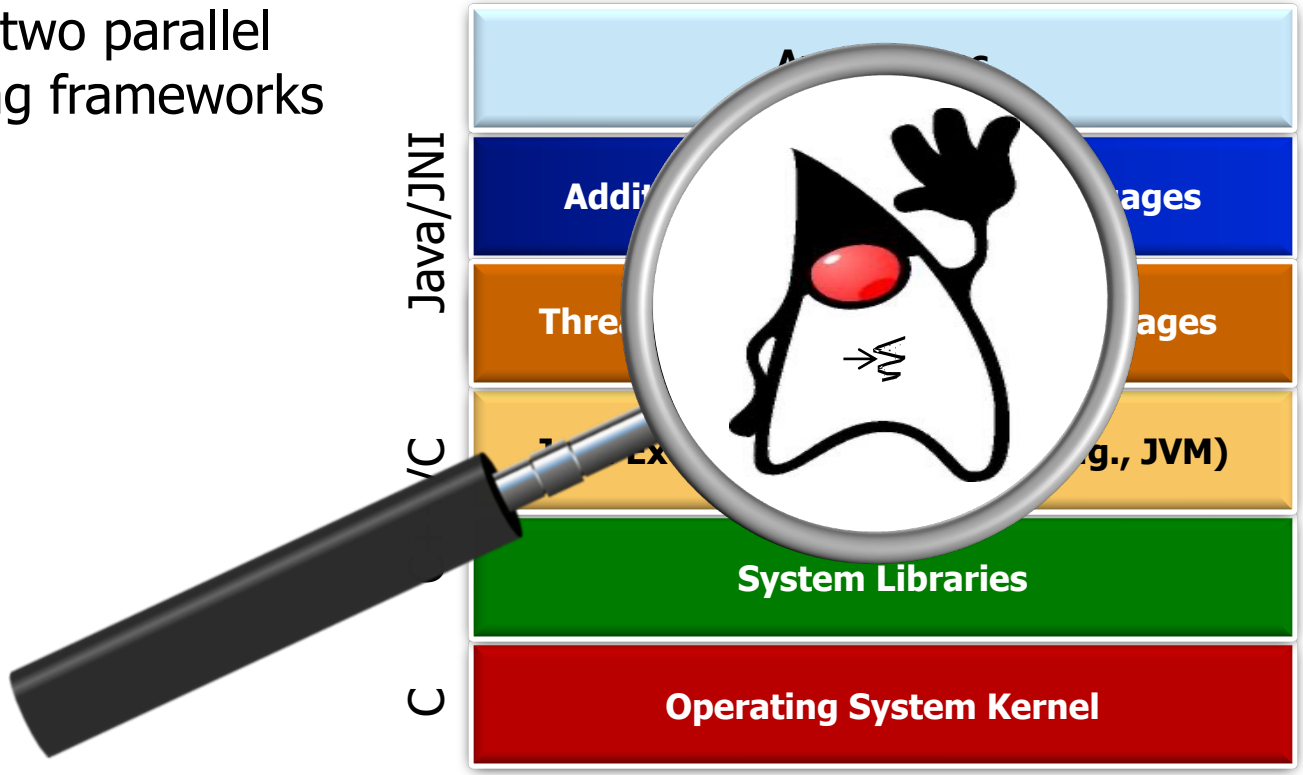
These parallel functional programming frameworks leverage the object-oriented fork-join pool framework by default

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

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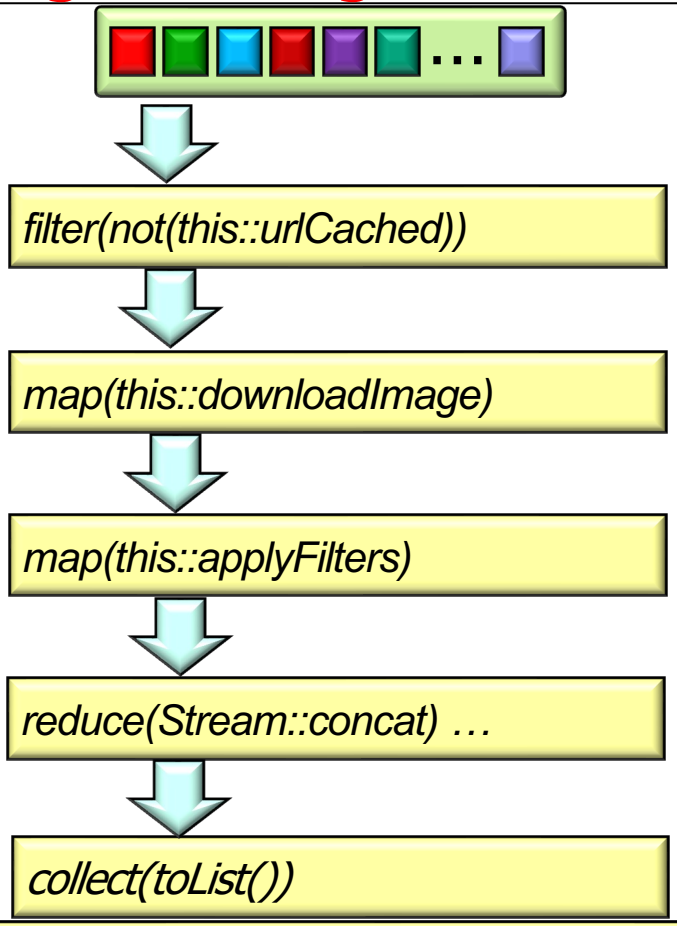

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Overview of Parallel Functional Programming Frameworks

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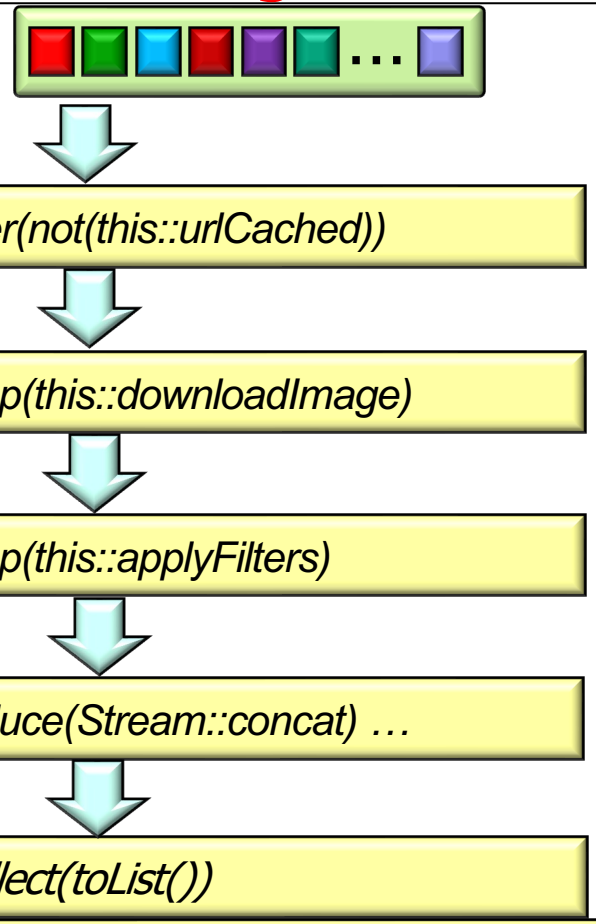
  1. Parallel streams

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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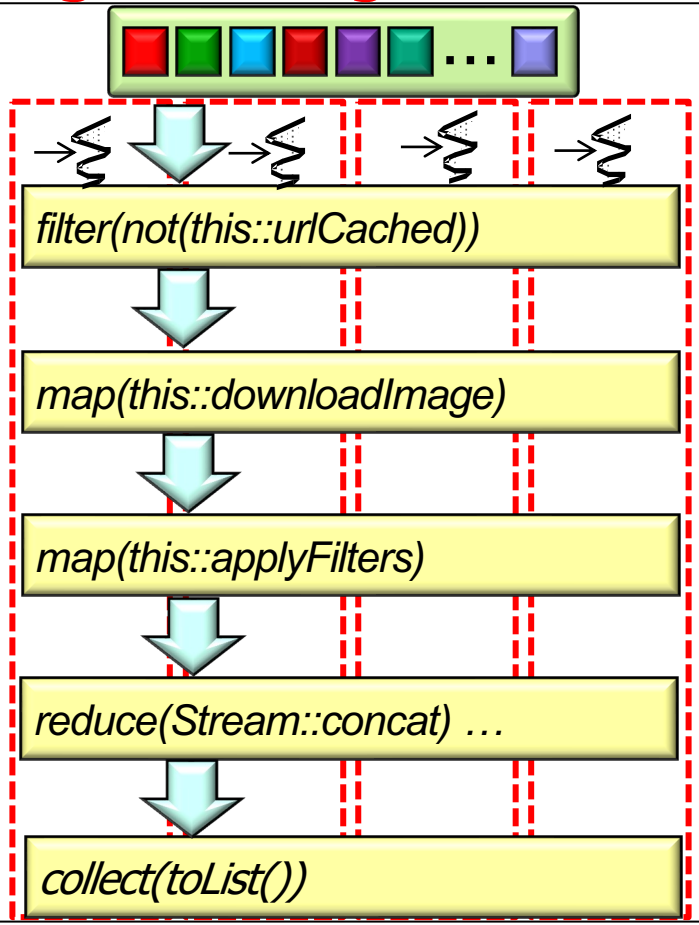
  1. Parallel streams

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



Overview of Parallel Functional Programming Frameworks

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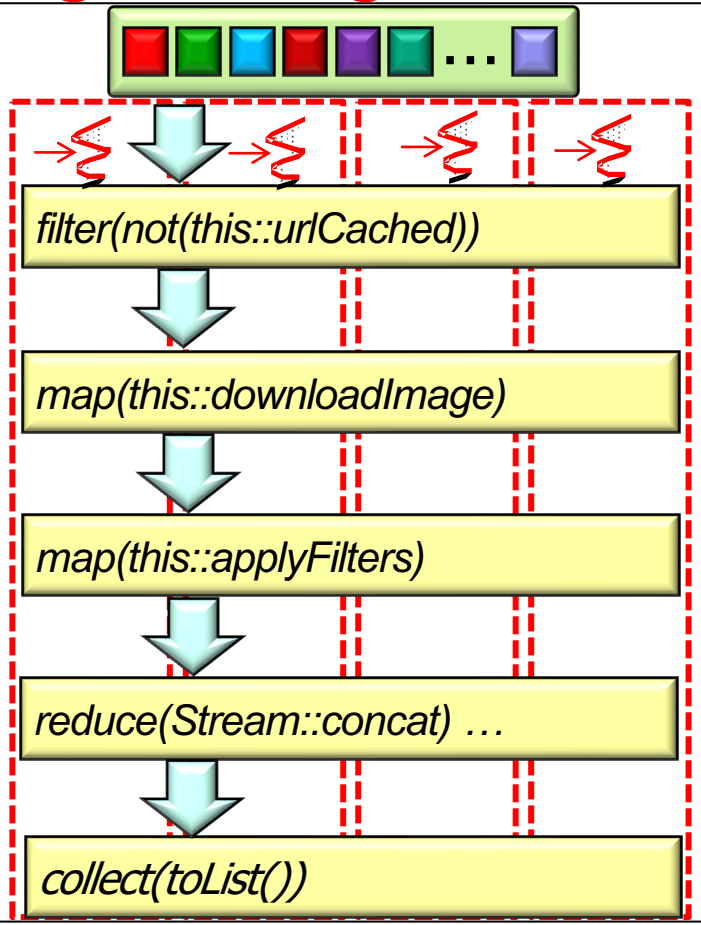
  - These chunks of data are mapped to multiple threads (& cores) & thus processed in parallel



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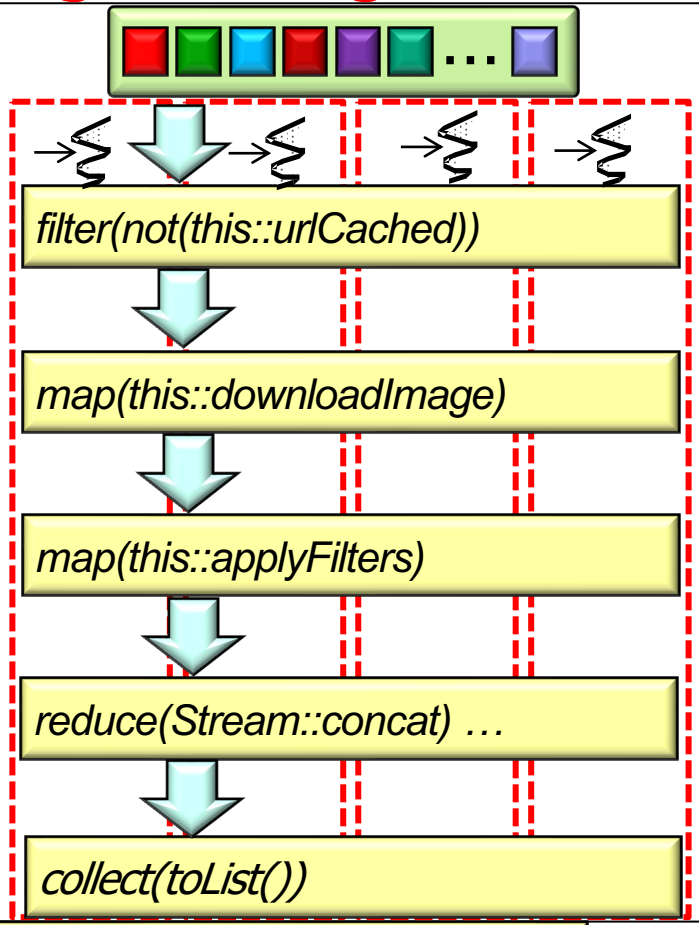

See dzone.com/articles/common-fork-join-pool-and-streams

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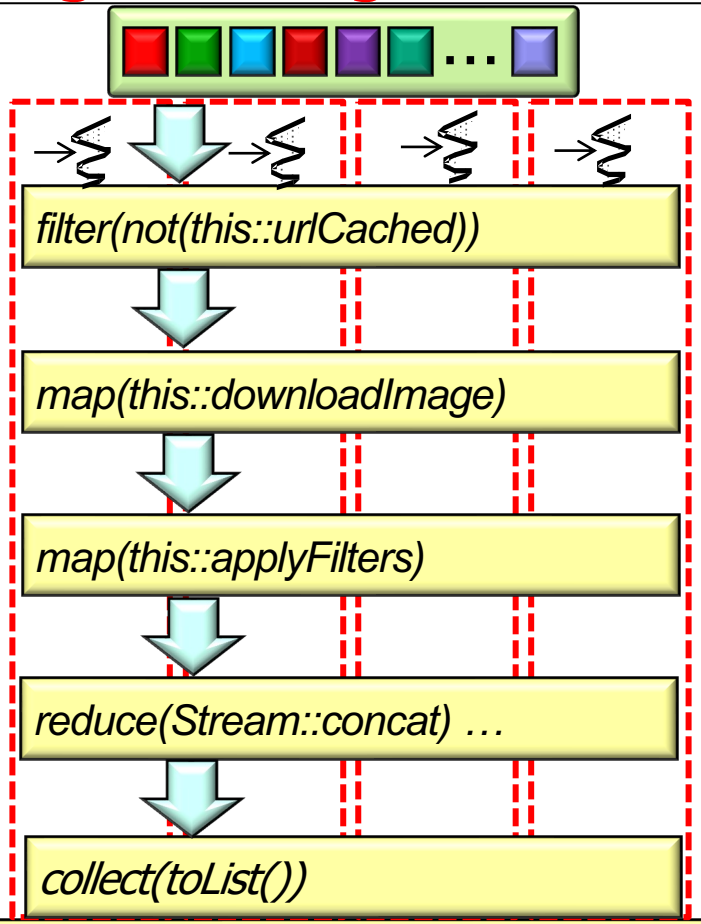

Parallel streams provide fine-grained data parallelism functional programming

Overview of Parallel Functional Programming Frameworks

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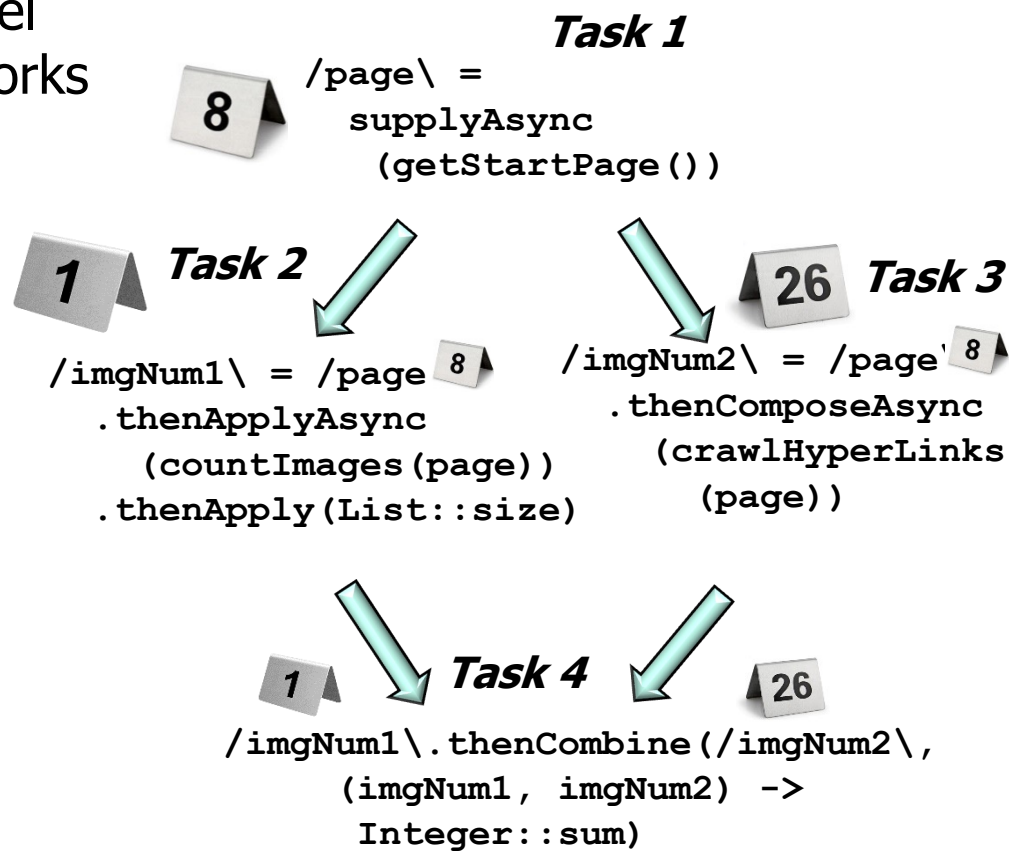
  1. Parallel streams
  2. **Completable futures**



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

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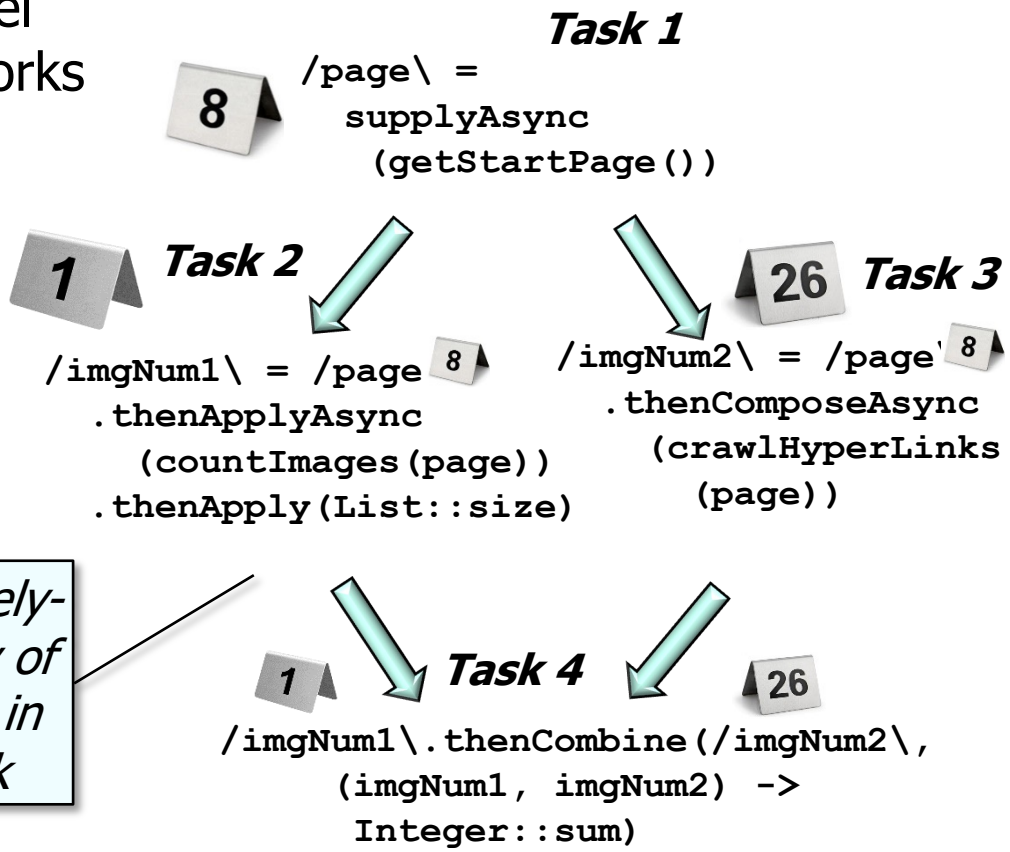

Count the # of images in a recursively-defined folder structure using many of the asynchronous features defined in the completable future framework

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

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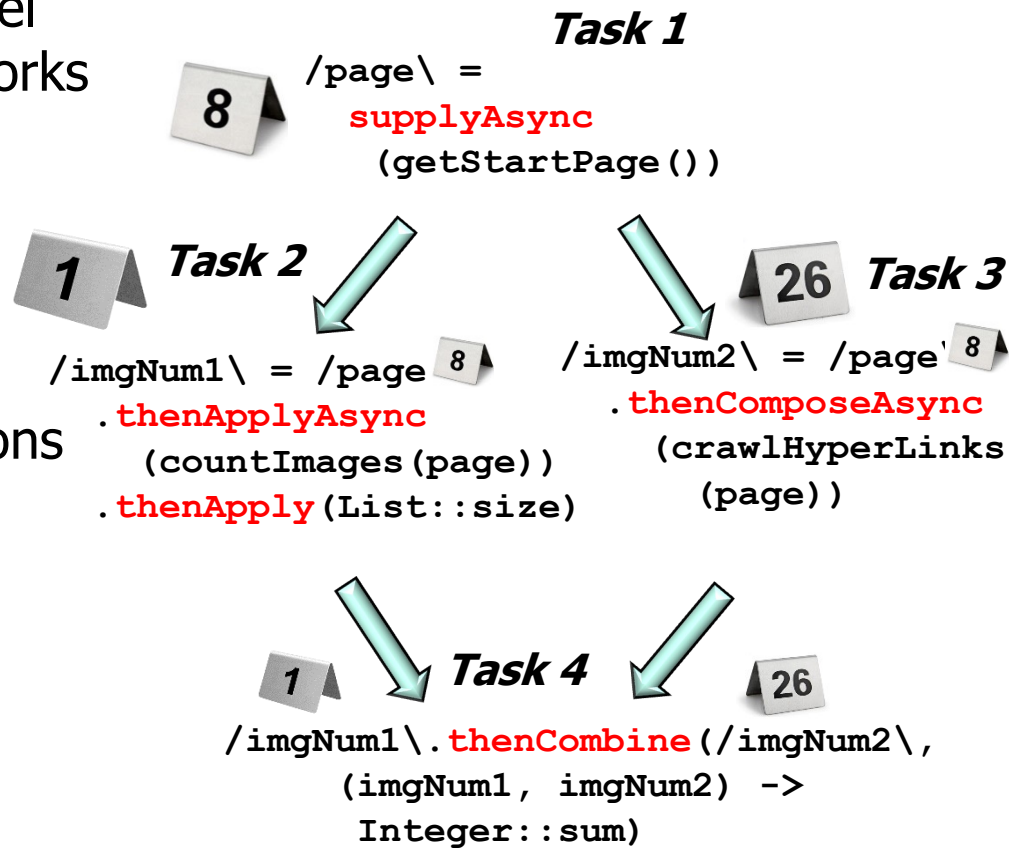
     - Supports dependent actions that are triggered upon the completion of async operations



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

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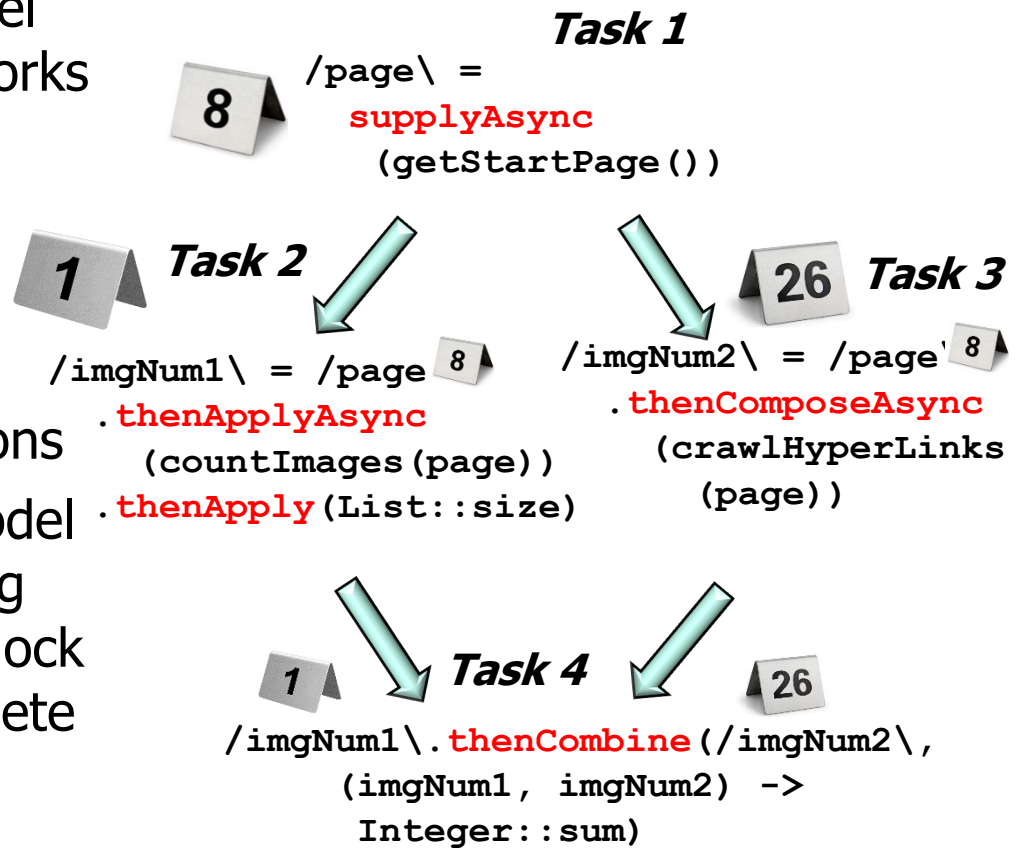
     - Supports dependent actions that are triggered upon the completion of async operations
       - Async operations are a model of concurrent programming where the caller doesn't block waiting for callee to complete



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

Overview of Parallel Functional Programming Frameworks

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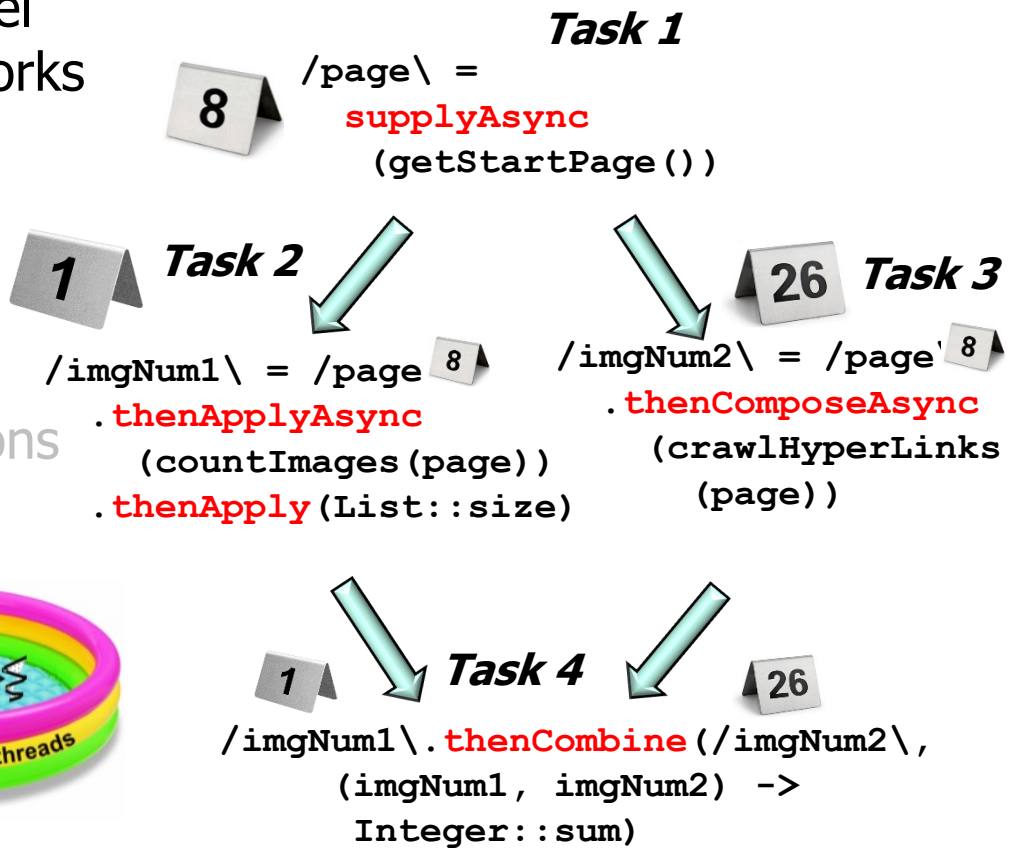
     - Supports dependent actions that are triggered upon the completion of async operations
     - Can also leverage the Java common fork-join pool



See www.baeldung.com/java-completablefuture

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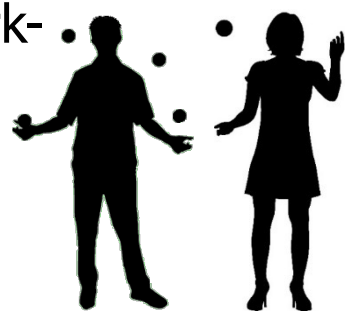

Task 1

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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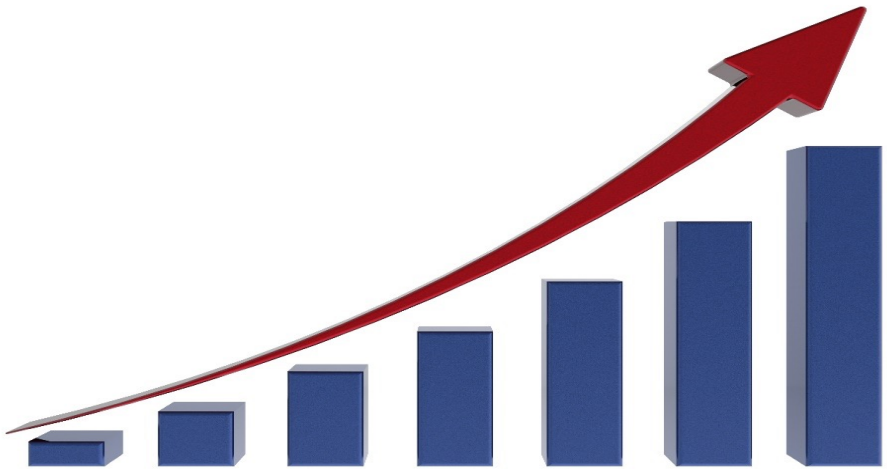
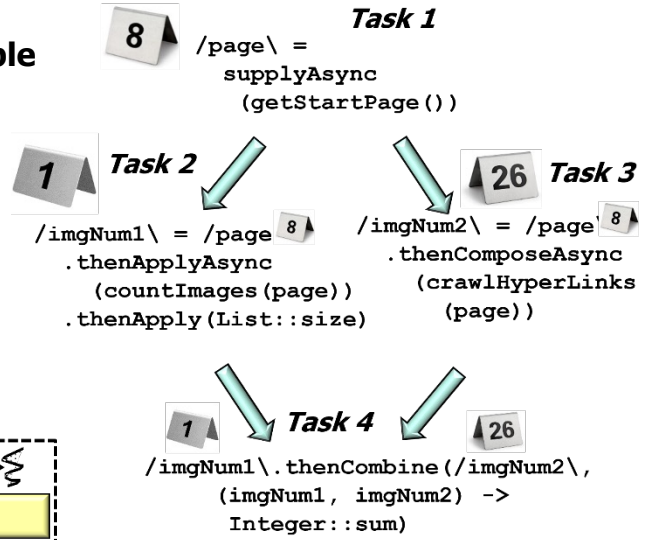
  - These frameworks perform well on modern multi-core processors, while also enhancing productivity



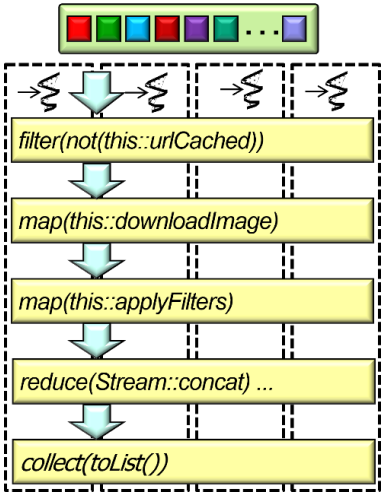
Evaluating Pros & Cons of Parallel Functional Programming Frameworks

- 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 Futures



Parallel Streams



ForkJoinPool

See en.wikipedia.org/wiki/Facade_pattern

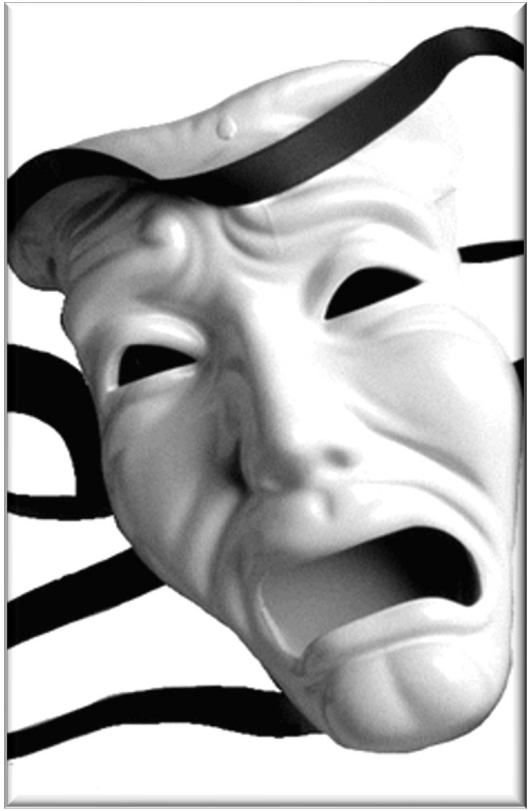
Evaluating Pros & Cons of Parallel Functional Programming Frameworks

- 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

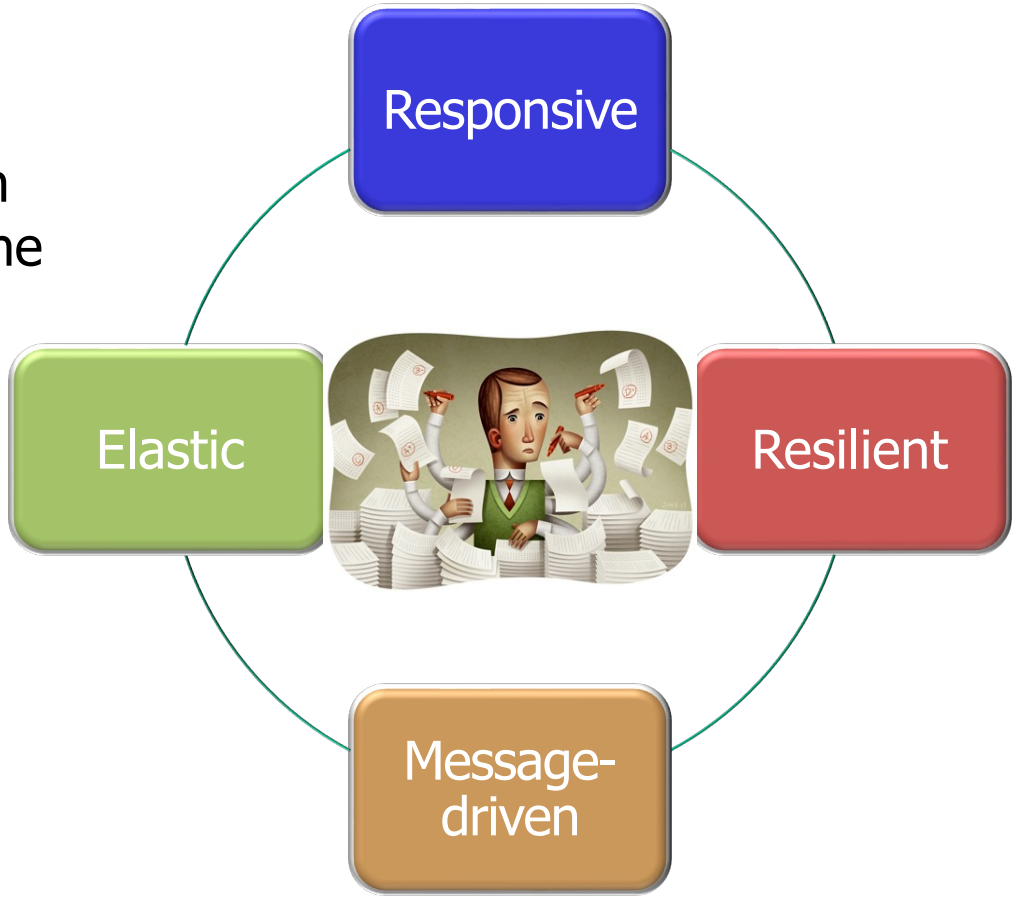
Evaluating Pros & Cons of Parallel Functional Programming Frameworks

- Cons of the parallel functional programming frameworks



Evaluating Pros & Cons of Parallel Functional Programming Frameworks

- Cons of the parallel functional programming frameworks
  - 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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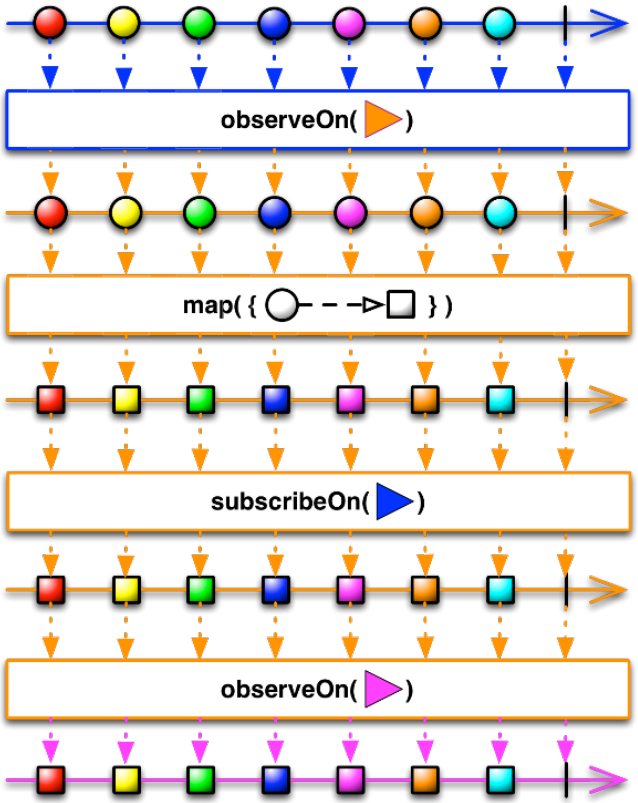
Motivates the need for Java reactive streams frameworks, which integrate streams & asynchrony more intentionally

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)

Discussion Questions

a. Which of the following statements accurately describes the cons of the parallel functional programming frameworks in Java as mentioned in the presentation?

   a. *These frameworks do not perform well on modern multi-core processors*

   b. *The frameworks require extensive explicit synchronization & threading*

   c. *They don't fully integrate streams with asynchrony to achieve the goals of the reactive programming paradigm*

   d. *They only focus on task parallelism & ignore data parallelism*