The Structure & Functionality of the Java Completable Futures Framework

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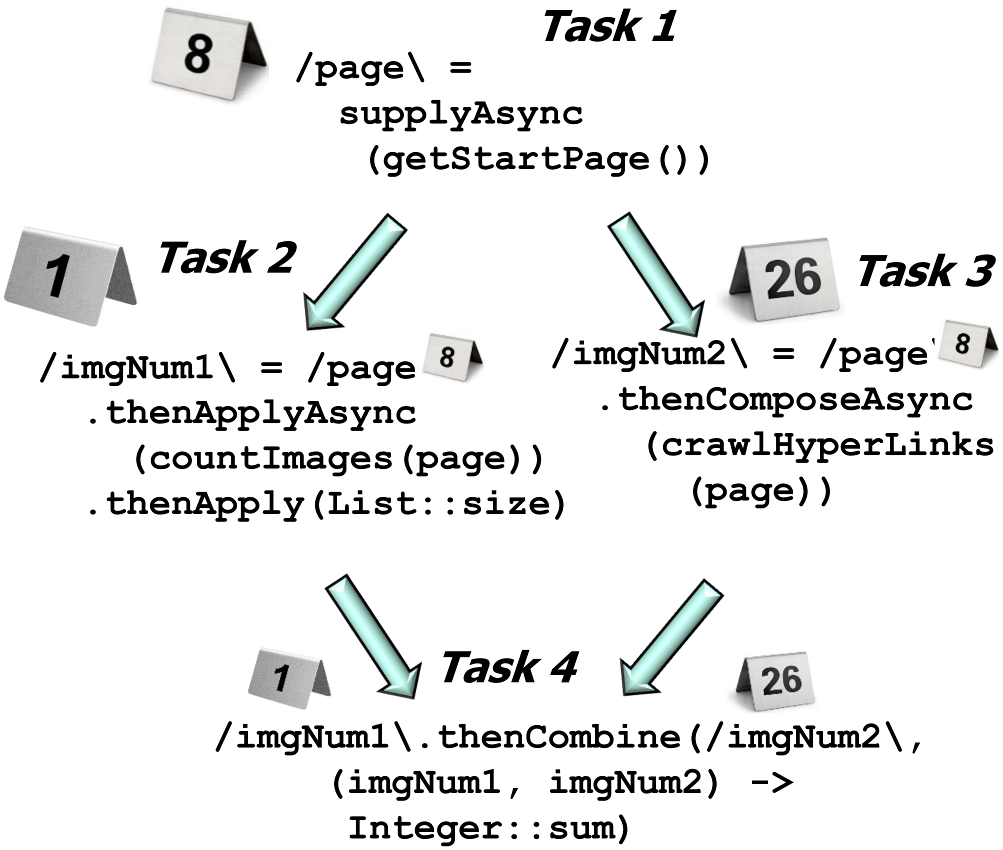
Learning Objectives in this Part of the Lesson

- Understand the key principles underlying reactive programming
- Recognize the Java completable futures framework's structure & functionality

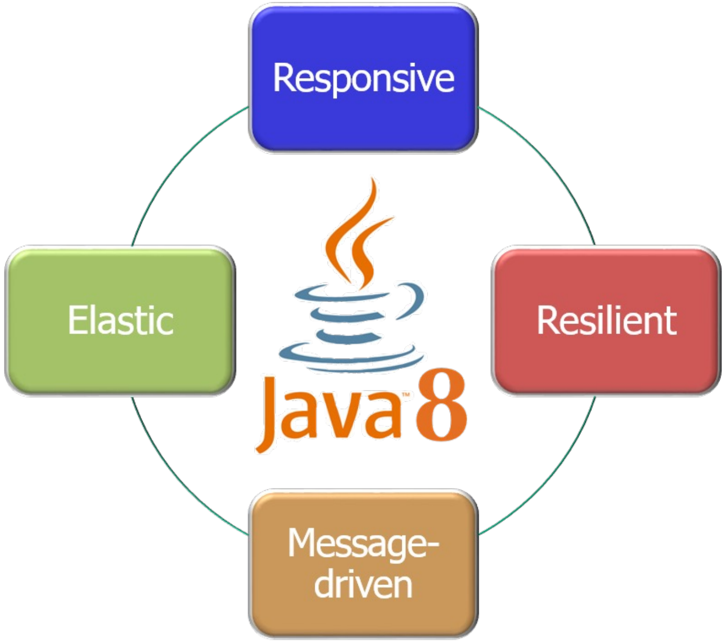


See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex19

Overview of the Java Completable Futures Framework

Overview of the Java Completable Futures Framework

- Java's completable futures framework provides an asynchronous & reactive parallel programming model



Class CompletableFuture<T>

java.lang.Object
    java.util.concurrent.CompletableFuture<T>

All Implemented Interfaces:

CompletionStage<T>, Future<T>

```
public class CompletableFuture<T>
extends Object
implements Future<T>, CompletionStage<T>
```

A `Future` that may be explicitly completed (setting its value and status), and may be used as a `CompletionStage`, supporting dependent functions and actions that trigger upon its completion.

When two or more threads attempt to `complete`, `completeExceptionally`, or `cancel` a CompletableFuture, only one of them succeeds.

In addition to these and related methods for directly manipulating status and results, CompletableFuture implements interface `CompletionStage` with the following policies:

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

Overview of the Java Completable Futures Framework

- Java's completable futures framework provides an asynchronous & reactive parallel programming model
  - As a baseline, consider a web crawler implementation that's synchronous

***Step 1**: Get start page*

***Step 2**: Count images on the page*

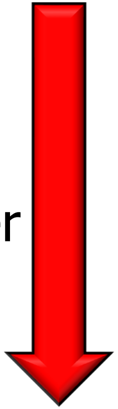
***Step 3**: Count images on all hyperlinked pages*

***Step 4**: Combine results to create the total*

See en.wikipedia.org/wiki/Web_crawler

Overview of the Java Completable Futures Framework

- Java's completable futures framework provides an asynchronous & reactive parallel programming model
  - As a baseline, consider a web crawler implementation that's synchronous
    - The time needed to perform all these steps is the sum of each step sequentially



***Step 1**: Get start page*

***Step 2**: Count images on the page*

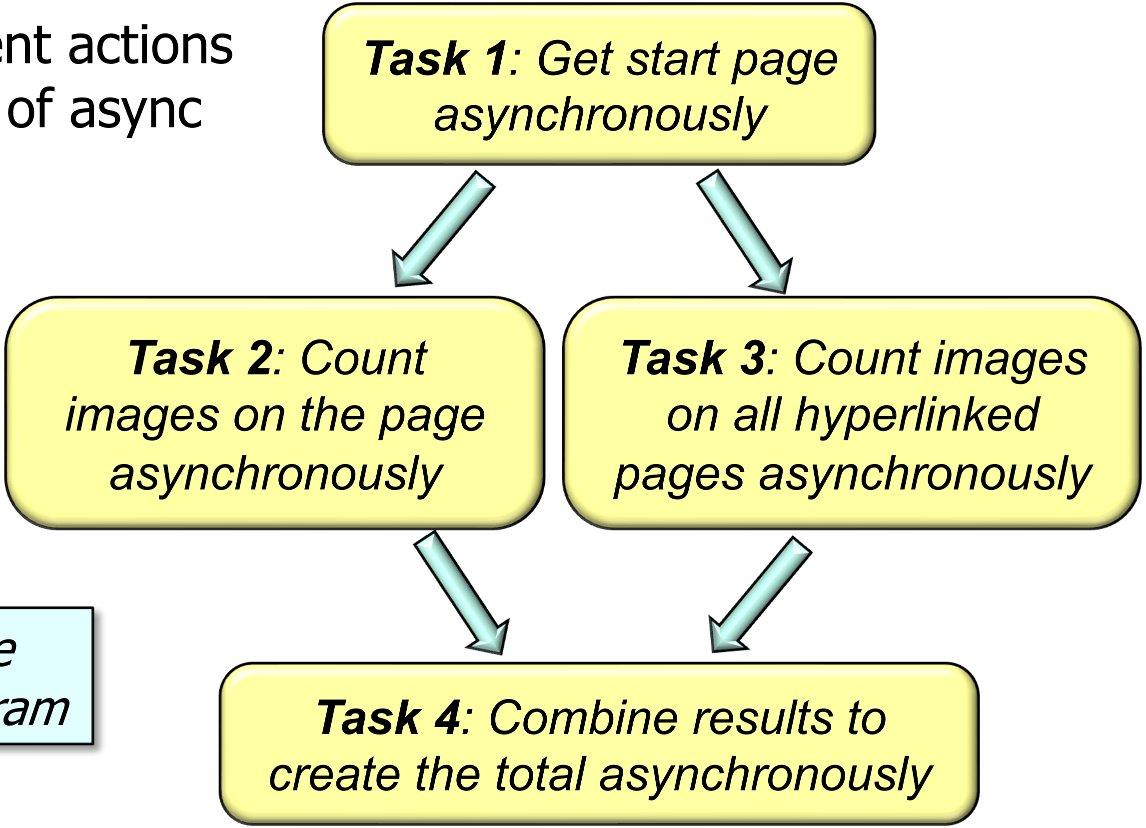
***Step 3**: Count images on all hyperlinked pages*

***Step 4**: Combine results to create the total*

See en.wikipedia.org/wiki/Sequential_algorithm

Overview of the Java Completable Futures Framework

- In contrast, Java's completable futures framework supports dependent actions that trigger upon completion of async operations



These dependencies can be modeled via a data flow diagram

See en.wikipedia.org/wiki/Data-flow_diagram

Overview of the Java Completable Futures Framework

- In contrast, Java's completable futures framework supports dependent actions that trigger upon completion of async operations

8

Task 1

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

1

Task 2

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

8

26

Task 3

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

8

Async operations can be forked, chained, & joined

1

Task 4

26

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

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Overview of the Java Completable Futures Framework

- In contrast, Java's completable futures framework supports dependent actions that trigger upon completion of async operations

Task 1

```
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```

Task 2

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

Task 3

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

Task 4

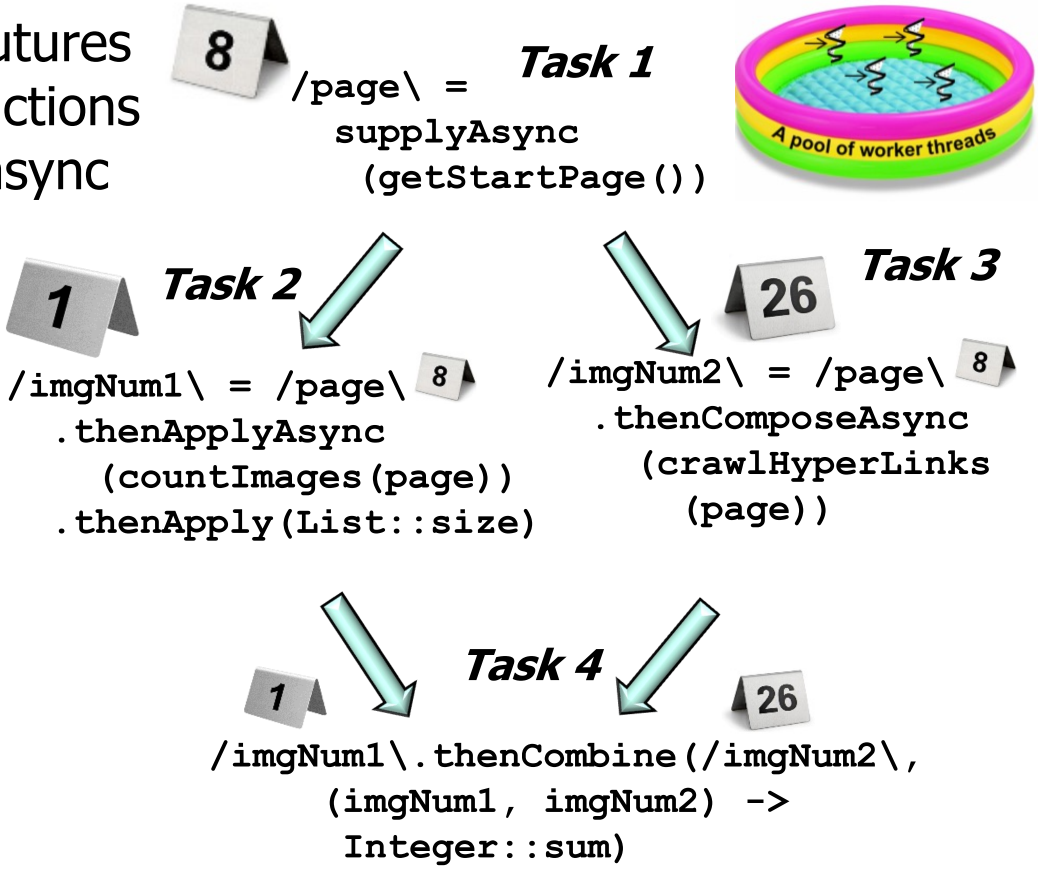
```
/imgNum1\.thenCombine(/imgNum2\,
  (imgNum1, imgNum2) ->
    Integer::sum)
```

Enables async programming to resemble sync programming via "completion stages"

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

Overview of the Java Completable Futures Framework

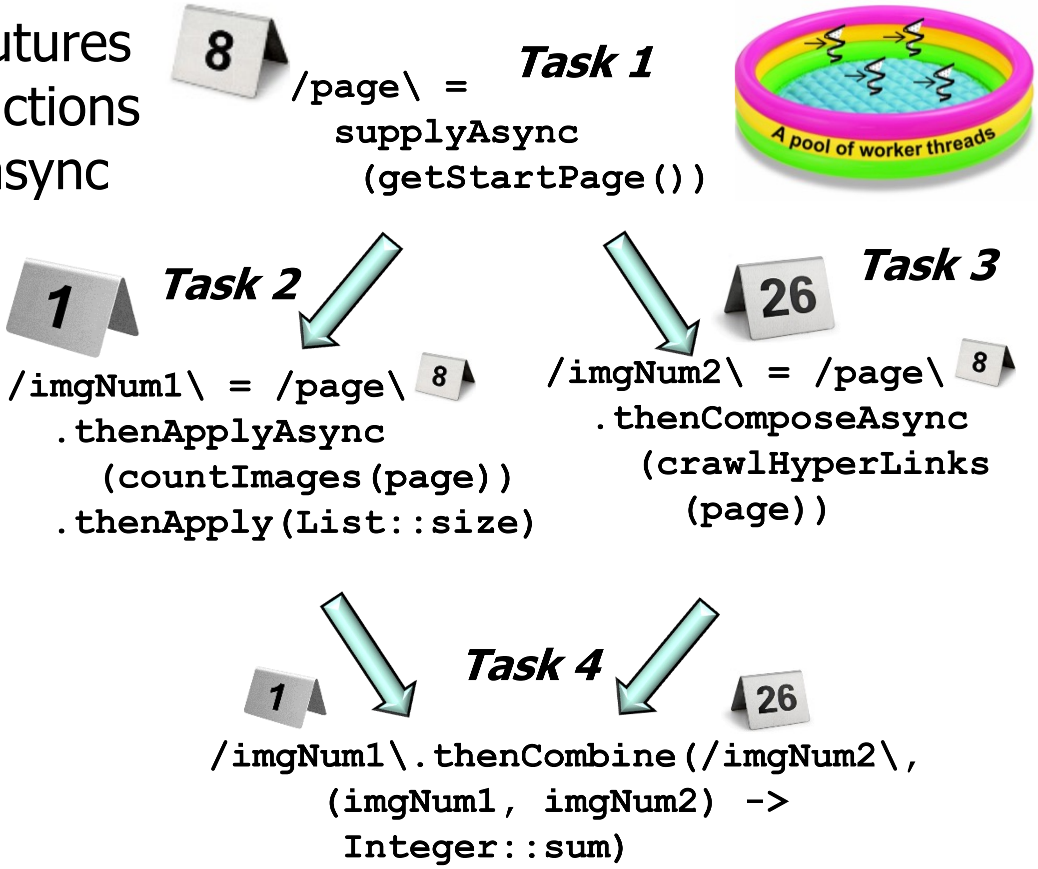
- In contrast, Java's completable futures framework supports dependent actions that trigger upon completion of async operations
  - These async operations can run in a thread pool



See www.nurkiewicz.com/2013/05/java-8-definitive-guide-to.html

Overview of the Java Completable Futures Framework

- In contrast, Java's completable futures framework supports dependent actions that trigger upon completion of async operations
  - These async operations can run in a thread pool
    - Either a (common) fork-join pool or various types of pre- or user-defined thread pools



Overview of the Java Completable Futures Framework

- In contrast, Java's completable futures framework supports dependent actions that trigger upon completion of async operations
  - These async operations can run in a thread pool
  - The time needed to perform these tasks depends on how well tasks can be parallelized

$$\text{Speedup}(N) = \frac{1}{(1-P)+\frac{P}{N}}$$

Serial part of job = 1 (100%) - Parallel part

Parallel part is divided up by N workers

Task 1

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

Task 2

```
1 /imgNum1\ = /page\ 8
  .thenApplyAsync
    (countImages(page))
  .thenApply(List::size)
```

Task 3

```
26 /imgNum2\ = /page\ 8
  .thenComposeAsync
    (crawlHyperLinks
      (page))
```

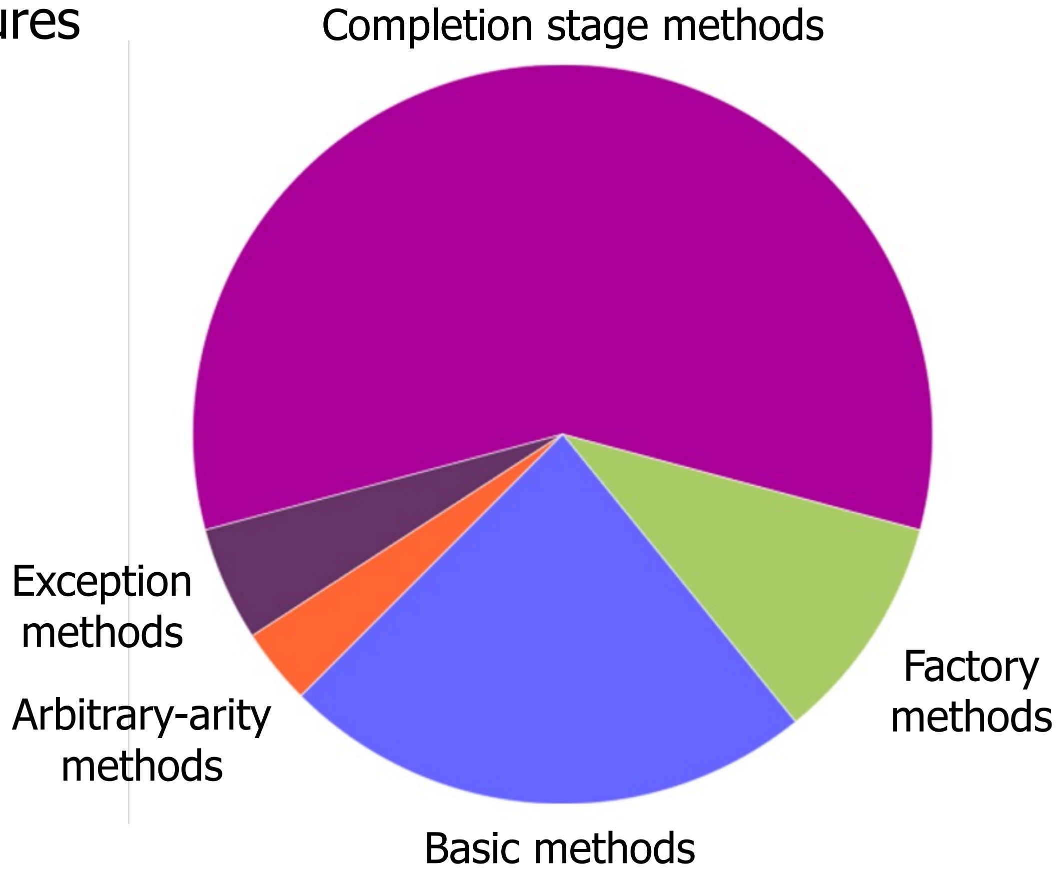
Task 4

```
1 26
/imgNum1\.thenCombine(/imgNum2\,
  (imgNum1, imgNum2) ->
    Integer::sum)
```

See en.wikipedia.org/wiki/Amdahl's_law

Overview of the Java Completable Futures Framework

- The entire Java completable futures framework resides in one public class with 60+ methods



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

Overview of the Java Completable Futures Framework

- Java completable futures, sequential streams, & functional programming features can be combined nicely!!

HTML page to download

<HTML><BODY>…</BODY></HTML>

↓

page.select("a[href]")

↓

stream()

↓

map(url -> countImages(…, url, …))

↓

collect(toFuture())

↓

thenApply(IntStream::sum)

See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex19

Overview of the Java Completable Futures Framework

- Java completable futures often need no explicit synchronization or threading when developing parallel programs!

HTML page to download

<HTML><BODY>…</BODY></HTML>

page.select("a[href]")

stream()

map(url -> countImages(…, url, …))

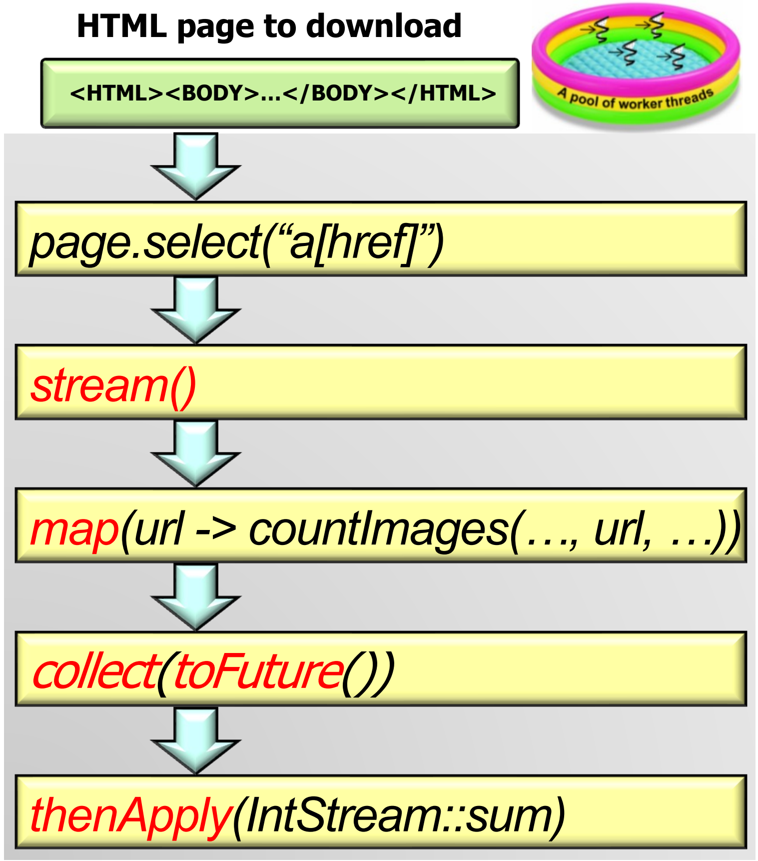
collect(toFuture())

thenApply(IntStream::sum)

Alleviates many accidental & inherent complexities of parallel programming

Overview of the Java Completable Futures Framework

- Java completable futures often need no explicit synchronization or threading when developing parallel programs!



Java class libraries handle locking needed to protect shared mutable state

End of the Structure & Functionality of the Java Completable Futures Framework