Advanced Java Completable Future Features: Applying Completion Stage Methods

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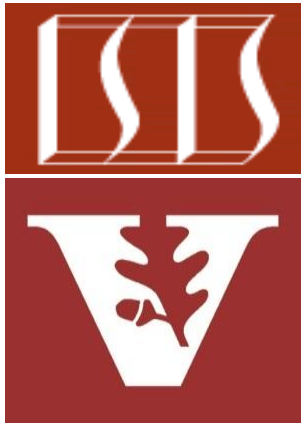

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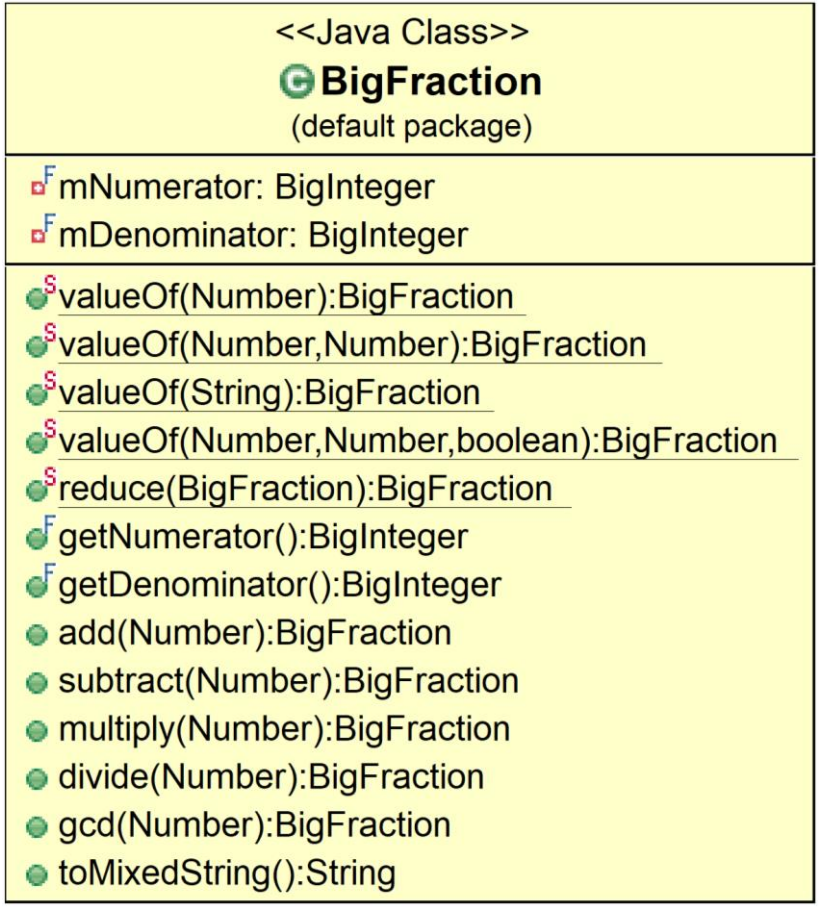
Learning Objectives in this Part of the Lesson

- Understand advanced features of completable futures, e.g.
  - Factory methods initiate async computations
  - Completion stage methods chain together actions to perform async result processing & composition
    - Method grouping
    - Single stage methods
    - Two stage methods (and)
    - Two stage methods (or)
    - Apply these methods



See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex8

Applying Completable Future Completion Stage Methods

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void testFractionMultiplications1() {
   ...
   Stream.generate(() -> makeBigFraction(new Random(), false))

         .limit(sMAX_FRACTIONS)

         .map(reduceAndMultiplyFractions)

         .collect(FuturesCollector.toFuture())

         .thenAccept(ex8::sortAndPrintList);
}
```

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}
```

Generate a bounded # of large, random, & unreduced fractions

See docs.oracle.com/javase/8/docs/api/java/util/stream/Stream.html#generate

Applying Completable Future Completion Stage Methods

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```
BigFraction makeBigFraction(Random random, boolean reduced) {
  BigInteger numerator =
    new BigInteger(150000, random);

  BigInteger denominator =
    numerator.divide(BigInteger
                     .valueOf(random.nextInt(10) + 1));

  return BigFraction.valueOf(numerator,
                             denominator,
                             reduced);
}
```

Factory method that creates a large & random big fraction

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  return BigFraction.valueOf(numerator,
                             denominator,
                             reduced);
}
```

A random # generator & a flag indicating whether to reduce the BigFraction

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    numerator.divide(BigInteger
                     .valueOf(random.nextInt(10) + 1));

  return BigFraction.valueOf(numerator,
                             denominator,
                             reduced);
}
```

Make a random numerator uniformly distributed over range 0 to (2^{150000} - 1)

See docs.oracle.com/javase/8/docs/api/java/math/BigInteger.html#BigInteger

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  BigInteger denominator =
    numerator.divide(BigInteger
                     .valueOf(random.nextInt(10) + 1));

  return BigFraction.valueOf(numerator,
                             denominator,
                             reduced);
}
```

Make a denominator by dividing the numerator by random # between 1 & 10

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  BigInteger numerator =
    new BigInteger(150000, random);

  BigInteger denominator =
    numerator.divide(BigInteger
                     .valueOf(random.nextInt(10) + 1));

  return BigFraction.valueOf(numerator,
                             denominator,
                             reduced);
}
```

Return a BigFraction w/the numerator & denominator

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```
static void testFractionMultiplications1() {
   ...
   Stream.generate(() -> makeBigFraction(new Random(), false))

         .limit(sMAX_FRACTIONS)

         .map(reduceAndMultiplyFraction)

         .collect(FuturesCollector.toFuture())

         .thenAccept(ex8::sortAndPrintList);
}
```

Reduce & multiply all these big fractions asynchronously

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void testFractionMultiplications1() {
  Function<BigFraction, CompletableFuture<BigFraction>>
    reduceAndMultiplyFraction = unreducedFrac ->
      CompletableFuture


        .supplyAsync(() -> BigFraction.reduce(unreducedFrac))

        .thenCompose(reducedFrac -> CompletableFuture
                     .supplyAsync(() -> reducedFrac
                                  .multiply(sBigFraction)));

  ...
```

Lambda function that asynchronously reduces & multiplies big fractions

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```
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  Function<BigFraction, CompletableFuture<BigFraction>>
    reduceAndMultiplyFraction = unreducedFrac ->
      CompletableFuture
        .supplyAsync(() -> BigFraction.reduce(unreducedFrac))

        .thenCompose(reducedFrac -> CompletableFuture
                     .supplyAsync(() -> reducedFrac
                                  .multiply(sBigFraction)));

  ...
```

Asynchronously reduce a big fraction

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```
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  Function<BigFraction, CompletableFuture<BigFraction>>
    reduceAndMultiplyFraction = unreducedFrac ->
      CompletableFuture


        .supplyAsync(() -> BigFraction.reduce(unreducedFrac))

        .thenCompose(reducedFrac -> CompletableFuture
                     .supplyAsync(() -> reducedFrac
                                  .multiply(sBigFraction)));
  ...
```

Asynchronously multiply big fractions

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void testFractionMultiplications1() {
  Function<BigFraction, CompletableFuture<BigFraction>>
    reduceAndMultiplyFraction = unreducedFrac ->
      CompletableFuture
```

thenCompose() acts like flatMap() to ensure one level of CompletableFuture nesting

```
        .supplyAsync(() -> BigFraction.reduce(unreducedFrac))

        .thenCompose(reducedFrac -> CompletableFuture
                     .supplyAsync(() -> reducedFrac
                                  .multiply(sBigFraction)));

  ...
```

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void testFractionMultiplications2() {
  Function<BigFraction, CompletableFuture<BigFraction>>
    reduceAndMultiplyFraction = unreducedFrac ->
      CompletableFuture


        .supplyAsync(() -> BigFraction.reduce(unreducedFrac))

        .thenApplyAsync(reducedFrac ->
                        reducedFrac.multiply(sBigFraction)));
  ...
```

thenApplyAsync() is an alternative means to avoid calling supplyAsync() again

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void testFractionMultiplications1() {
   ...
   Stream.generate(() -> makeBigFraction(new Random(), false))

         .limit(sMAX_FRACTIONS)

         .map(reduceAndMultiplyFraction)

         .collect(FuturesCollector.toFuture())

         .thenAccept(ex8::sortAndPrintList);
}
```

Outputs a stream of completable futures to async operations on big fractions

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   ...
   Stream.generate(() -> makeBigFraction(new Random(), false))

         .limit(sMAX_FRACTIONS)

         .map(reduceAndMultiplyFraction)

         .collect(FuturesCollector.toFuture())

         .thenAccept(ex8::sortAndPrintList);
}
```

Return a single future to a list of big fractions being reduced & multiplied asynchronously

See lesson on "*Advanced Java Completable Future Features: Implementing FuturesCollector*"

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   Stream.generate(() -> makeBigFraction(new Random(), false))

         .limit(sMAX_FRACTIONS)

         .map(reduceAndMultiplyFraction)

         .collect(FuturesCollector.toFuture())

         .thenAccept(ex8::sortAndPrintList);
}
```

Sort & print results when all async computations complete

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void sortAndPrintList(List<BigFraction> list) {
```

Sort & print a list of reduced & multiplied big fractions

```
  CompletableFuture<List<BigFraction>> quickSortF =
    CompletableFuture.supplyAsync(() -> quickSort(list));

  CompletableFuture<List<BigFraction>> mergeSortF =
    CompletableFuture.supplyAsync(() -> mergeSort(list));


  quickSortF.acceptEither(mergeSortF, sortedList ->
      sortedList.forEach(frac -> display(frac.toMixedString())));
}; ...
```

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void sortAndPrintList(List<BigFraction> list) {


  CompletableFuture<List<BigFraction>> quickSortF =
    CompletableFuture.supplyAsync(() -> quickSort(list));

  CompletableFuture<List<BigFraction>> mergeSortF =
    CompletableFuture.supplyAsync(() -> mergeSort(list));

  quickSortF.acceptEither(mergeSortF, sortedList ->
      sortedList.forEach(frac -> display(frac.toMixedString())));
}; ...
```

Asynchronously apply quick sort & merge sort!

Applying Completable Future Completion Stage Methods

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```
static void sortAndPrintList(List<BigFraction> list) {


  CompletableFuture<List<BigFraction>> quickSortF =
    CompletableFuture.supplyAsync(() -> quickSort(list));

  CompletableFuture<List<BigFraction>> mergeSortF =
    CompletableFuture.supplyAsync(() -> mergeSort(list));


  quickSortF.acceptEither(mergeSortF, sortedList ->
      sortedList.forEach(frac -> display(frac.toMixedString())));
}; ...
```

Select whichever result finishes first..

Applying Completable Future Completion Stage Methods

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```
static void sortAndPrintList(List<BigFraction> list) {


  CompletableFuture<List<BigFraction>> quickSortF =
    CompletableFuture.supplyAsync(() -> quickSort(list));

  CompletableFuture<List<BigFraction>> mergeSortF =
    CompletableFuture.supplyAsync(() -> mergeSort(list));
```

If future is already completed the action runs in the thread that registered the action

```
  quickSortF.acceptEither(mergeSortF, sortedList ->
      sortedList.forEach(frac -> display(frac.toMixedString())));
}; ...
```

Applying Completable Future Completion Stage Methods

- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void sortAndPrintList(List<BigFraction> list) {


  CompletableFuture<List<BigFraction>> quickSortF =
    CompletableFuture.supplyAsync(() -> quickSort(list));

  CompletableFuture<List<BigFraction>> mergeSortF =
    CompletableFuture.supplyAsync(() -> mergeSort(list));

  quickSortF.acceptEither(mergeSortF, sortedList ->
      sortedList.forEach(frac -> display(frac.toMixedString())));
}; ...
```

Otherwise, the action runs in the thread in which the previous stage ran

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- We show key completion stage methods via the testFractionMultiplications1() method that multiplies big fractions using a stream of CompletableFutures

```
static void sortAndPrintList(List<BigFraction> list) {


  CompletableFuture<List<BigFraction>> quickSortF =
    CompletableFuture.supplyAsync(() -> quickSort(list));

  CompletableFuture<List<BigFraction>>
    CompletableFuture.supplyAsync(() ->


  quickSortF.acceptEither(mergeSortF, sortedList ->
      sortedList.forEach(frac -> display(frac.toMixedString())));
}; ...
```

acceptEither() does *not* cancel the second future after the first one completes

End of Advanced Java CompletableFuture Features: Applying Completion Stage Methods