Java Parallel Streams Internals: Overcoming Limitations with flatMap() in Parallel Streams

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Learning Objectives in this Part of the Lesson

- Understand parallel stream internals, e.g.
  - Know what can change & what can't
  - Partition a data source into "chunks"
  - Process chunks in parallel via the common fork-join pool
  - Configure the Java parallel stream common fork-join pool
  - Recognize how to overcome limitations with flatMap() in parallel streams

```
var result =
  generateOuterStream
    (Options.instance()
     .iterations())

 .flatMap(...::innerStream)

 .anyMatch(...);
```

See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex35

Limitations with flatMap() in Parallel Streams

Limitations with flatMap() in Parallel Streams

- The Java flatMap() implementation oddly forces sequential processing

```
<R> Stream<R> flatMap
   (Function<? super P_OUT,
    ? extends Stream<? extends R>>
    mapper) {
 ...
  public void accept(P_OUT u) {
    try(Stream<? extends R> result
        = mapper.apply(u)) {
    if (result != null) {
      if (...) {
        result
        .sequential()
        .forEach(downstream);
      ...
}
```

BEWARE!

This code always runs sequentially for "inner streams" that use flatMap()

See stackoverflow.com/questions/45038120/parallel-flatmap-always-sequential/66386078

Limitations with flatMap() in Parallel Streams

- This limitation renders flatMap() useless for parallel streams

```
var result = IntStream
  .rangeClosed(1, outerCount)
  .boxed()
  .parallel()

  .flatMap(innerCount -> IntStream
     .rangeClosed(1, innerCount)
     .boxed()
     .parallel())

  .anyMatch(...);
```

Limitations with flatMap() in Parallel Streams

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```
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   .rangeClosed(1, outerCount)
   .boxed()
   .parallel()

   .flatMap(innerCount -> IntStream
      .rangeClosed(1, innerCount)
      .boxed()
      .parallel())

   .anyMatch(...);
```

The outer stream emits a parallel stream of Integer objects from 1 to outerCount

Limitations with flatMap() in Parallel Streams

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```
var result = IntStream
    .rangeClosed(1, outerCount)
    .boxed()
    .parallel()

    .flatMap(innerCount -> IntStream
        .rangeClosed(1, innerCount)
        .boxed()
        .parallel())

    .anyMatch(...);
```

Try using flatMap() to create an inner stream that emits Integer objects from 1 to innerCount in parallel

Limitations with flatMap() in Parallel Streams

- This limitation renders flatMap() useless for parallel streams

```
var result = IntStream
   .rangeClosed(1, outerCount)
   .boxed()
   .parallel()

   .flatMap(innerCount -> IntStream
      .rangeClosed(1, innerCount)
      .boxed()
      .parallel())

   .anyMatch(...);
```

Return true if all results are sequential, else false

Limitations with flatMap() in Parallel Streams

- This limitation renders flatMap() useless for parallel streams

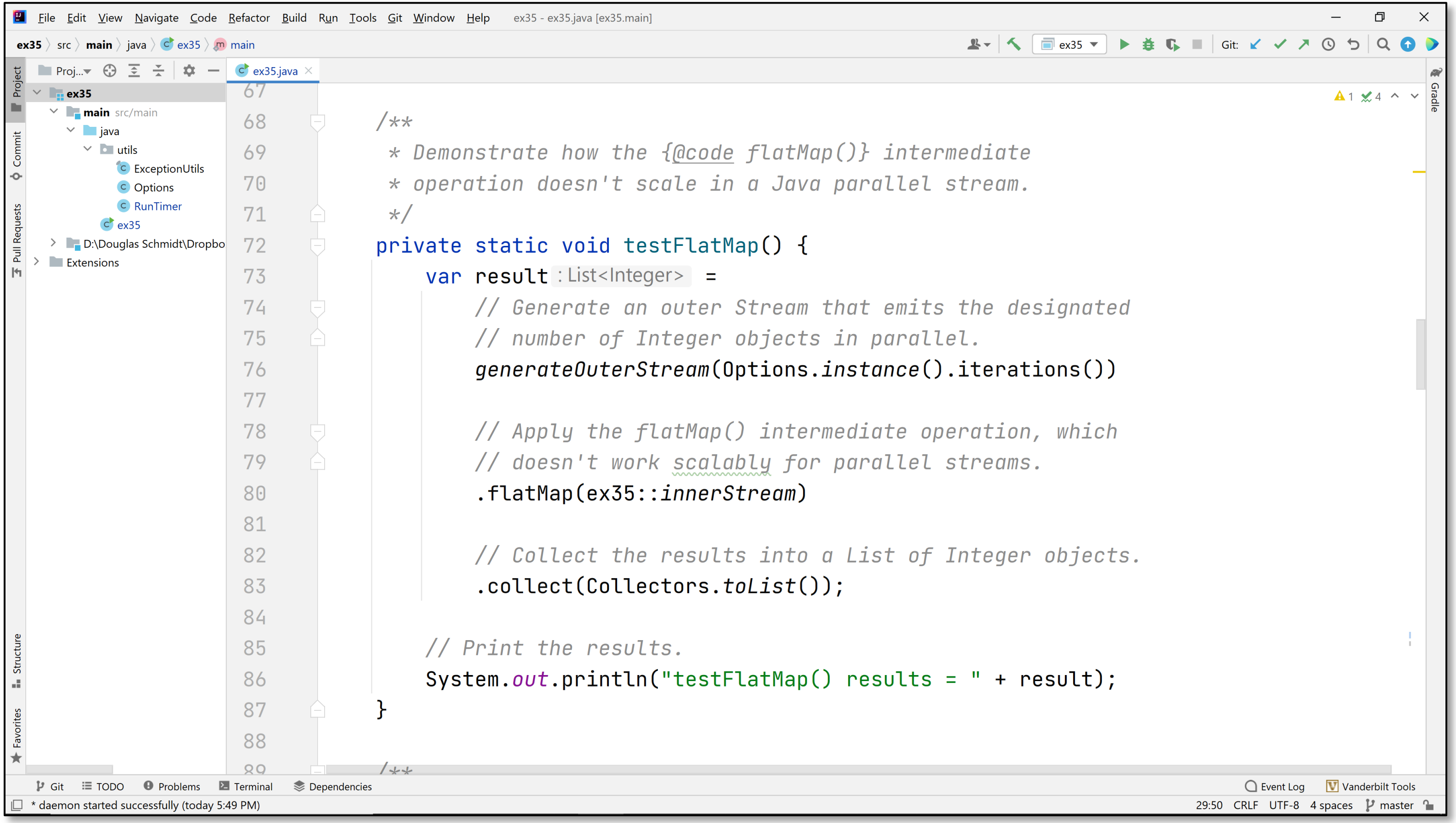
```
var result = IntStream
  .rangeClosed(1, outerCount)
  .boxed()
  .parallel()

  .flatMap(innerCount -> IntStream
     .rangeClosed(1, innerCount)
     .boxed()
     .parallel())

  .anyMatch(...);
```

This inner stream always runs sequentially for even though it designates .parallel() due to limitations with flatMap()

Limitations with flatMap() in Parallel Streams



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```java
    /**
     * Demonstrate how the {@code flatMap()} intermediate
     * operation doesn't scale in a Java parallel stream.
     */
    private static void testFlatMap() {
        var result : List<Integer>  =
            // Generate an outer Stream that emits the designated
            // number of Integer objects in parallel.
            generateOuterStream(Options.instance().iterations())

            // Apply the flatMap() intermediate operation, which
            // doesn't work scalably for parallel streams.
            .flatMap(ex35::innerStream)

            // Collect the results into a List of Integer objects.
            .collect(Collectors.toList());

        // Print the results.
        System.out.println("testFlatMap() results = " + result);
    }

    /**
```

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See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex35

Overcoming Limitations with flatMap() in Parallel Streams

Overcoming Limitations with flatMap() in Parallel Streams

- One workaround is to use reduce() with Stream.concat()

```
var result = IntStream
    .rangeClosed(1, outerCount)
    .boxed()
    .parallel()

    .map(innerCount -> IntStream
        .rangeClosed(1, innerCount)
        .boxed()
        .parallel())

    .reduce(Stream::concat)
    .orElse(Stream.empty())

    .anyMatch(...);
```

Overcoming Limitations with flatMap() in Parallel Streams

- One workaround is to use reduce() with Stream.concat()

```
var result = IntStream
  .rangeClosed(1, outerCount)
  .boxed()
  .parallel()

  .map(innerCount -> IntStream
     .rangeClosed(1, innerCount)
     .boxed()
     .parallel())

  .reduce(Stream::concat)
  .orElse(Stream.empty())

  .anyMatch(...);
```

The outer stream emits a parallel stream of Integer objects from 1 to outerCount

Overcoming Limitations with flatMap() in Parallel Streams

- One workaround is to use reduce() with Stream.concat()

```
var result = IntStream
   .rangeClosed(1, outerCount)
   .boxed()
   .parallel()

   .map(innerCount -> IntStream
      .rangeClosed(1, innerCount)
      .boxed()
      .parallel())

   .reduce(Stream::concat)
   .orElse(Stream.empty())

   .anyMatch(...);
```

Use map() to create an inner stream-of-streams that emits Integer objects from 1 to innerCount in parallel

Overcoming Limitations with flatMap() in Parallel Streams

- One workaround is to use reduce() with Stream.concat()

```
var result = IntStream
  .rangeClosed(1, outerCount)
  .boxed()
  .parallel()

  .map(innerCount -> IntStream
     .rangeClosed(1, innerCount)
     .boxed()
     .parallel())

  .reduce(Stream::concat)
  .orElse(Stream.empty())

  .anyMatch(...);
```

Manually flatten the stream-of-streams into a stream of Integer objects

Overcoming Limitations with flatMap() in Parallel Streams

- One workaround is to use reduce() with Stream.concat()

```
var result = IntStream
   .rangeClosed(1, outerCount)
   .boxed()
   .parallel()

   .map(innerCount -> IntStream
      .rangeClosed(1, innerCount)
      .boxed()
      .parallel())

   .reduce(Stream::concat)
   .orElse(Stream.empty())

   .anyMatch(...);
```

Needed to handle the case where the stream is empty

Overcoming Limitations with flatMap() in Parallel Streams

- One workaround is to use reduce() with Stream.concat()

```
var result = IntStream
  .rangeClosed(1, outerCount)
  .boxed()
  .parallel()

  .map(innerCount -> IntStream
     .rangeClosed(1, innerCount)
     .boxed()
     .parallel())

  .reduce(Stream::concat)
  .orElse(Stream.empty())

  .anyMatch(...);
```

Return true if all results are sequential, else false

Overcoming Limitations with flatMap() in Parallel Streams

- One workaround is to use reduce() with Stream.concat()

```
var result = IntStream
   .rangeClosed(1, outerCount)
   .boxed()
   .parallel()

   .map(innerCount -> IntStream
      .rangeClosed(1, innerCount)
      .boxed()
      .parallel())

   .reduce(Stream::concat)
   .orElse(Stream.empty())

   .anyMatch(...);
```

This inner stream now runs in parallel, as intended

Overcoming Limitations with flatMap() in Parallel Streams

- Another workaround is to use mapMulti()

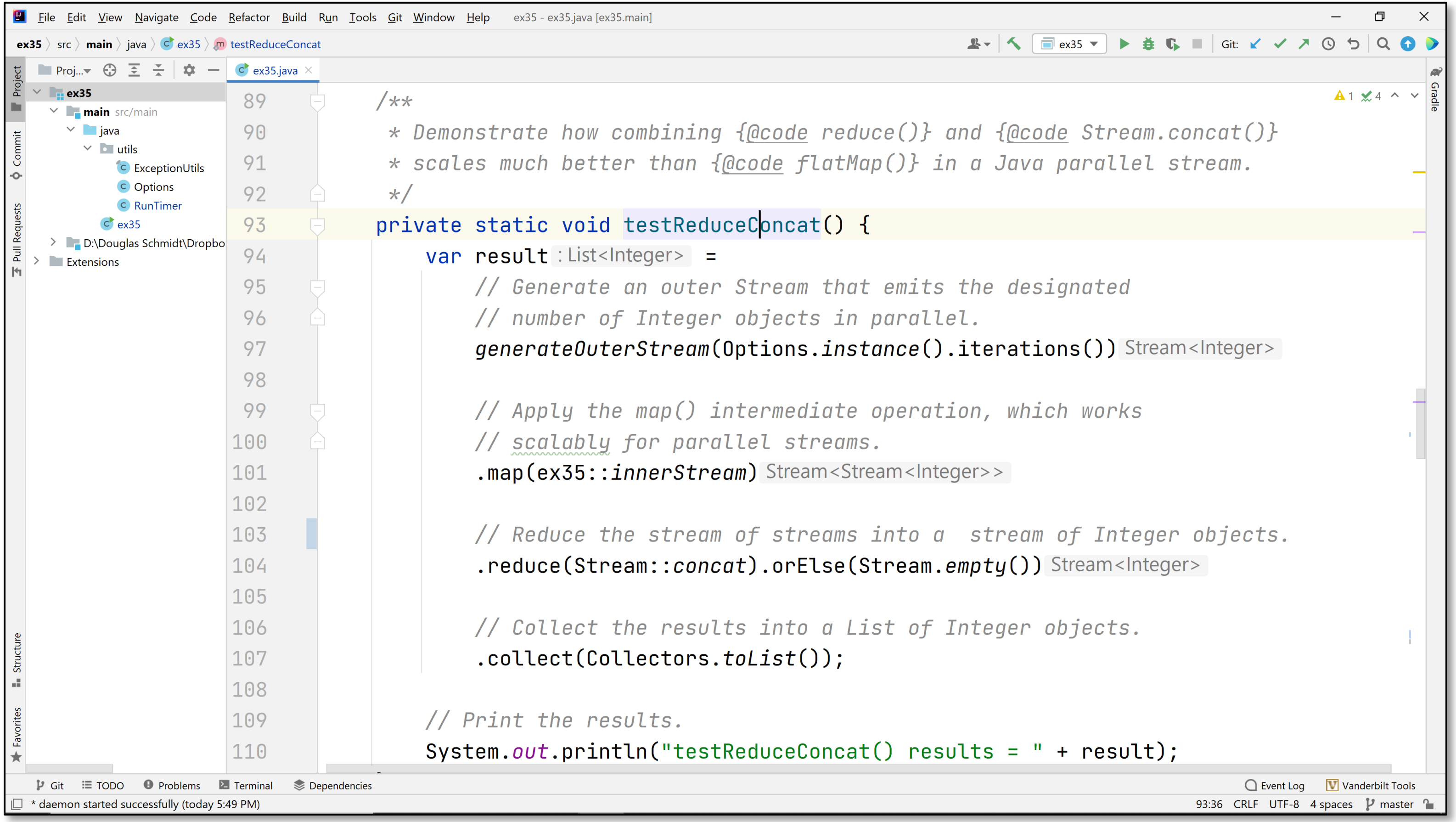
```
var result = IntStream
  .rangeClosed(1, outerCount)
  .boxed()
  .parallel()

  .mapMulti((innerCount,
             consumer) -> {
     int result = IntStream
       .rangeClosed(1, innerCount)
       .parallel()
       .mapMulti((i, c) -> ...)
       .sum();
     consumer.accept(result);})

  .allMatch(...);
```

This inner stream now also runs in parallel, as intended

Overcoming Limitations with flatMap() in Parallel Streams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```java
    /**
     * Demonstrate how combining {@code reduce()} and {@code Stream.concat()}
     * scales much better than {@code flatMap()} in a Java parallel stream.
     */
    private static void testReduceConcat() {
        var result : List<Integer> =
            // Generate an outer Stream that emits the designated
            // number of Integer objects in parallel.
            generateOuterStream(Options.instance().iterations()) Stream<Integer>

            // Apply the map() intermediate operation, which works
            // scalably for parallel streams.
            .map(ex35::innerStream) Stream<Stream<Integer>>

            // Reduce the stream of streams into a  stream of Integer objects.
            .reduce(Stream::concat).orElse(Stream.empty()) Stream<Integer>

            // Collect the results into a List of Integer objects.
            .collect(Collectors.toList());

        // Print the results.
        System.out.println("testReduceConcat() results = " + result);
```

See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex35

End of Java Parallel Streams Internals: Overcoming Limitations with flatMap() in Parallel Streams