Java Parallel Streams Internals: Combining Results (Part 2)

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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
  • Perform a reduction to combine partial results into a single result
  • Be aware of common traps & pitfalls with parallel streams
Differences for collect() & reduce() in a Parallel Stream
Differences for `collect()` & `reduce()` in a Parallel Stream

- It’s important to understand the semantic differences between `collect()` & `reduce()`
It’s important to understand the semantic differences between `collect()` & `reduce()`, e.g.

Always test w/a parallel stream to detect mistakes wrt mutable vs. immutable reductions

```java
void buggyStreamReduce3a (boolean parallel) {

    Stream<String> wordStream = allWords.stream();

    if (parallel)
        wordStream.parallel();

    String words = wordStream
        .reduce(new StringBuilder(),
            StringBuilder::append,
            StringBuilder::append)
        .toString();
}
```

See `github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex17`
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    String words = wordStream
        .reduce(new StringBuilder(),
                StringBuilder::append,
                StringBuilder::append)
        .toString();
}
```

Convert a list of words into a stream of words

Naturally, this call doesn’t really do any work since streams are “lazy”
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    ...
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    if (parallel)
        wordStream.parallel();

    String words = wordStream.reduce(new StringBuilder(),
        StringBuilder::append,
        StringBuilder::append)
        .toString();
}
```

A stream can be dynamically switched to "parallel" mode!

See docs.oracle.com/javase/8/docs/api/java/util/stream/BaseStream.html#parallel
It’s important to understand the semantic differences between `collect()` & `reduce()`, e.g.

Always test with a parallel stream to detect mistakes wrt mutable vs. immutable reductions

```java
void buggyStreamReduce3a(
    boolean parallel) {
    ...
    Stream<String> wordStream =
        allWords.stream();
    ...
    if (parallel) {
        wordStream.parallel();
    } else {
        wordStream.sequential();
    }
    String words = wordStream
        .reduce(new StringBuilder(),
                String::append,
                StringBuilder::append)
        .toString();
}
```

The “last” call to `.parallel()` or `.sequential()` in a stream “wins”
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    Stream<String> wordStream =
        allWords.stream();
    if (parallel)
        wordStream.parallel();
    String words = wordStream
        .reduce(new StringBuilder(),
                  StringBuilder::append,
                  StringBuilder::append)
        .toString();
```

This code works when parallel is false since the StringBuilder is only called in a single thread

See docs.oracle.com/javase/8/docs/api/java/lang/StringBuilder.html
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```java
void buggyStreamReduce3a (boolean parallel) {
    ...
    Stream<String> wordStream = allWords.stream();
    if (parallel) {
        wordStream.parallel();
        String words = wordStream
            .reduce(new StringBuilder(),
                    StringBuilder::append, StringBuilder::append)
            .toString();
    }
}
```

This code fails when parallel is true since reduce() expects to do an "immutable" reduction
It’s important to understand the semantic differences between collect() & reduce(), e.g.

Always test w/a parallel stream to detect mistakes wrt mutable vs. immutable reductions

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    ...
    Stream<String> wordStream = allWords.stream();
    if (parallel)
        wordStream.parallel();
    String words = wordStream
        .reduce(new StringBuilder(),
                StringBuilder::append,
                StringBuilder::append)
        .toString();
```

There’s a race condition here since StringBuilder is not thread-safe.

See www.baeldung.com/java-string-builder-string-buffer
It’s important to understand the semantic differences between `collect()` & `reduce()`, e.g.

- Always test with a parallel stream to detect mistakes wrt mutable vs. immutable reductions
- One solution use `reduce()` with string concatenation

```java
void streamReduceConcat(boolean parallel) {
  ...
  Stream<String> wordStream = allWords.stream();
  if (parallel)
    wordStream.parallel();
  String words = wordStream
    .reduce(new String(),
    (x, y) -> x + y);
}
```

See [github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex17](https://github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex17)
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    ...  
    Stream<String> wordStream = allWords.stream();

    if (parallel)
        wordStream.parallel();

    String words = wordStream
        .reduce(new String(),
            (x, y) -> x + y);
}
```

This simple fix is inefficient due to string concatenation overhead.

See javarevisited.blogspot.com/2015/01/3-examples-to-concatenate-string-in-java.html
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- Always test with a parallel stream to detect mistakes wrt mutable vs. immutable reductions
- One solution use `reduce()` with string concatenation
- Another solution uses `collect()` with the joining collector

```java
void streamCollectJoining (boolean parallel) {
    ... 
    Stream<String> wordStream = allWords.stream();
    if (parallel)
        wordStream.parallel();
    String words = wordStream .collect(joining());
}
```

See [github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex17](https://github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex17)
Differences for `collect()` & `reduce()` in a Parallel Stream

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  - One solution use `reduce()` with string concatenation
  - Another solution uses `collect()` with the joining collector

```java
void streamCollectJoining (boolean parallel) {
    ...
    Stream<String> wordStream = allWords.stream();
    if (parallel)
        wordStream.parallel();
    String words = wordStream .collect(joining());
}
```

This is a much better solution!!

See [www.mkyong.com/java8/java-8-stringjoiner-example](http://www.mkyong.com/java8/java-8-stringjoiner-example)
Differences for collect() & reduce() in a Parallel Stream

- Also beware of issues related to associativity & identity with reduce()

```java
testDifferenceReduce(...) {
    long difference = LongStream
        .rangeClosed(1, 100)
        .parallel()
        .reduce(0L,
                (x, y) -> x - y);
}

testSum(long identity, ...) {
    long sum = LongStream
        .rangeClosed(1, 100)
        .reduce(identity,
            // Could use (x, y) -> x + y
                Math::addExact);
}
```

See [github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex17](https://github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex17)
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    long sum = LongStream
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        .reduce(identity,
                 // Could use (x, y) -> x + y
                 Math::addExact);
}
```

This code fails for a parallel stream since subtraction is not associative

Differences for collect() & reduce() in a Parallel Stream

- Also beware of issues related to associativity & identity with reduce()

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void testDifferenceReduce(...) {
    long difference = LongStream
        .rangeClosed(1, 100)
        .parallel()
        .reduce(0L,
               (x, y) -> x - y);
}
```

```java
void testSum(long identity, ...) {
    long sum = LongStream
        .rangeClosed(1, 100)
        .reduce(identity,
                 // Could use (x, y) -> x + y
                 Math::addExact);
}
```

This code fails if identity is not 0L

The “identity” of an OP is defined as “identity OP value == value” (& inverse)
Differences for collect() & reduce() in a Parallel Stream

• Also beware of issues related to associativity & identity with reduce()

```java
void testDifferenceReduce(...) {
  long difference = LongStream
    .rangeClosed(1, 100)
    .parallel()
    .reduce(0L,
            (x, y) -> x - y);
}

void testProd(long identity, ...) {
  long sum = LongStream
    .rangeClosed(1, 100)
    .reduce(identity,
             (x, y) -> x * y);
}
```

This code fails if identity is not 1L
Differences for collect() & reduce() in a Parallel Stream

- More good discussions about reduce() vs. collect() appear online

See [www.youtube.com/watch?v=oWIWEKNM5Aw](http://www.youtube.com/watch?v=oWIWEKNM5Aw)
End of Java Parallel Streams Internals: Combining Results (Part 2)