Java 8 Parallel SearchStreamGang Example (Part 2)

Douglas C. Schmidt
d.schmidt@vanderbilt.edu
www.dre.vanderbilt.edu/~schmidt

Professor of Computer Science

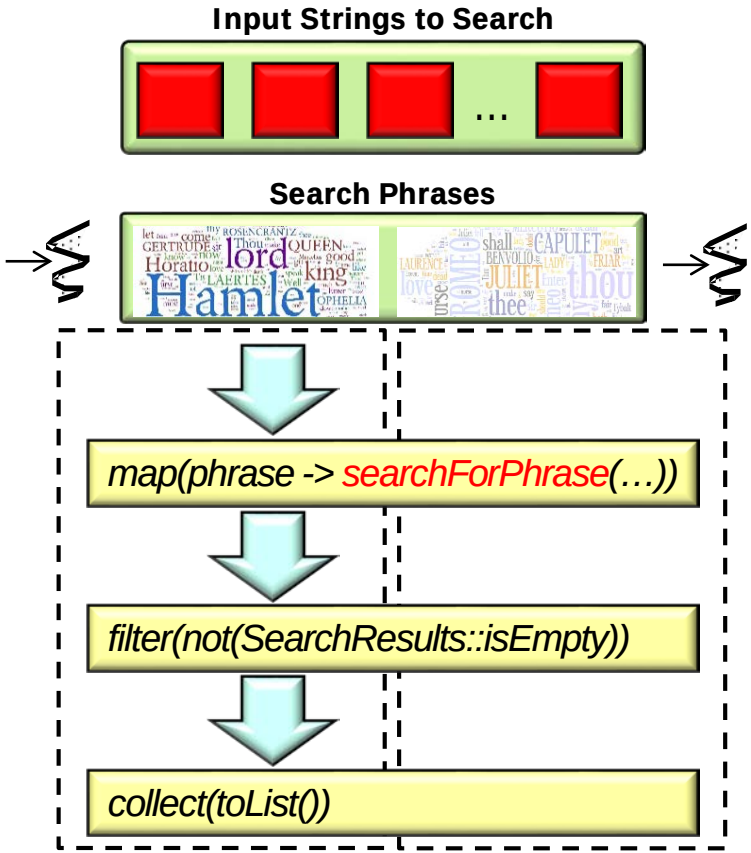
Institute for Software
Integrated Systems

Vanderbilt University
Nashville, Tennessee, USA

Learning Objectives in this Part of the Lesson

- Know how Java 8 parallel streams are applied in the SearchStreamGang
- Understand the pros & cons of the SearchWithParallelStreams class
- Recognize how a parallel spliterator can improve parallel stream performance

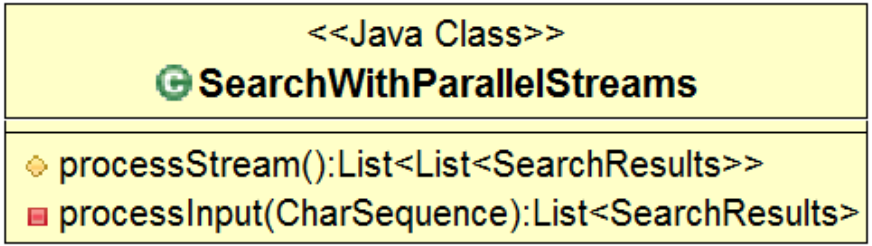
```
SearchResults searchForPhrase
  (..., boolean parallel) {
  return new SearchResults
    (..., StreamSupport.stream
      (new PhraseMatchSpliterator(...),
       parallel)
      .collect(toList()));
}
```



This solution addresses a “con” covered in the first part of this lesson

Learning Objectives in this Part of the Lesson

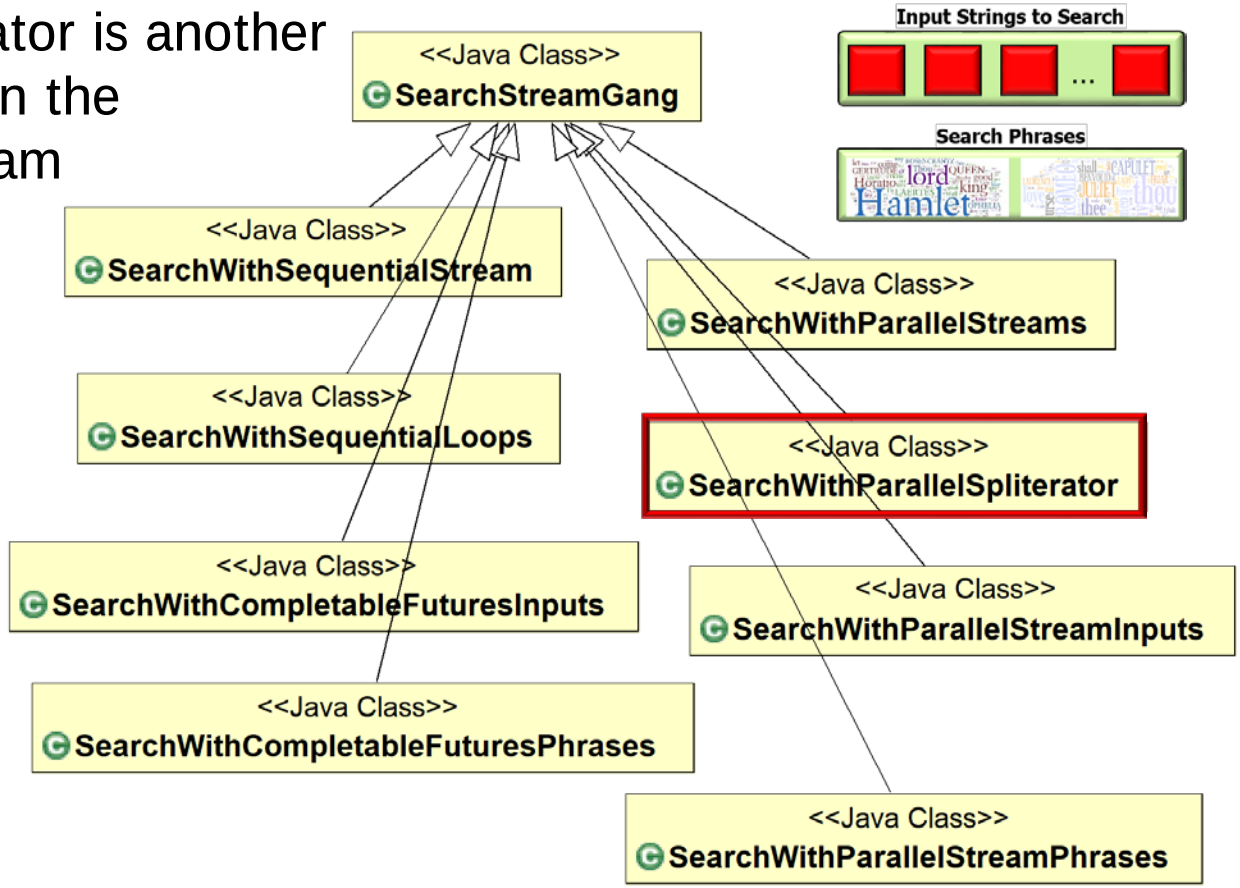
- Know how Java 8 parallel streams are applied in the SearchStreamGang
- Understand the pros & cons of the SearchWithParallelStreams class
- Recognize how a parallel spliterator can improve parallel stream performance
- Understand the pros & cons of the SearchWithParallelSpliterator class



Overview of SearchWith ParallelSpliterator

Overview of SearchWithParallelSpliterator

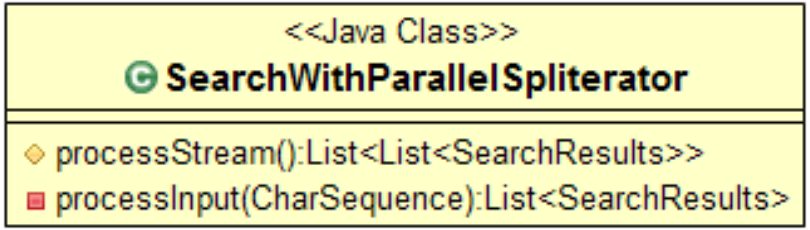
- SearchWithParallelSpliterator is another implementation strategy in the SearchStreamGang program



See SearchStreamGang/src/main/java/livelessons/streamgangs/SearchWithParallelSpliterator.java

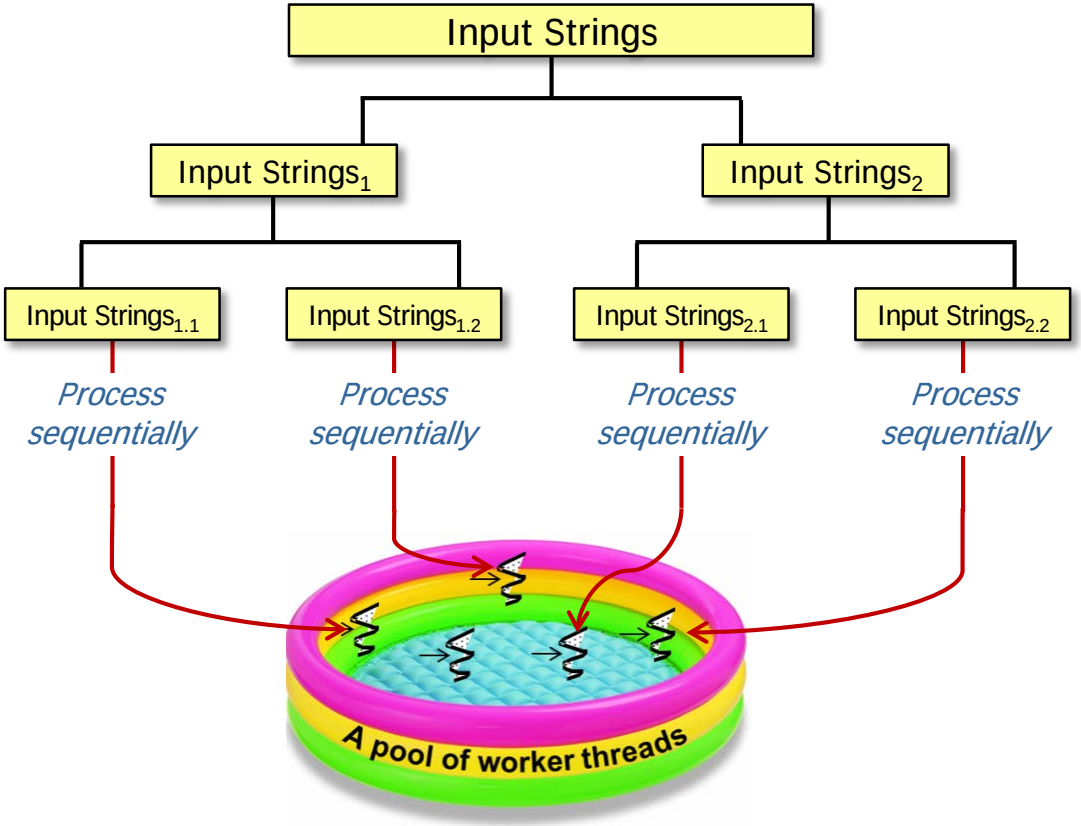
Overview of SearchWithParallelSpliterator

- SearchWithParallelSpliterator uses parallel streams in three ways



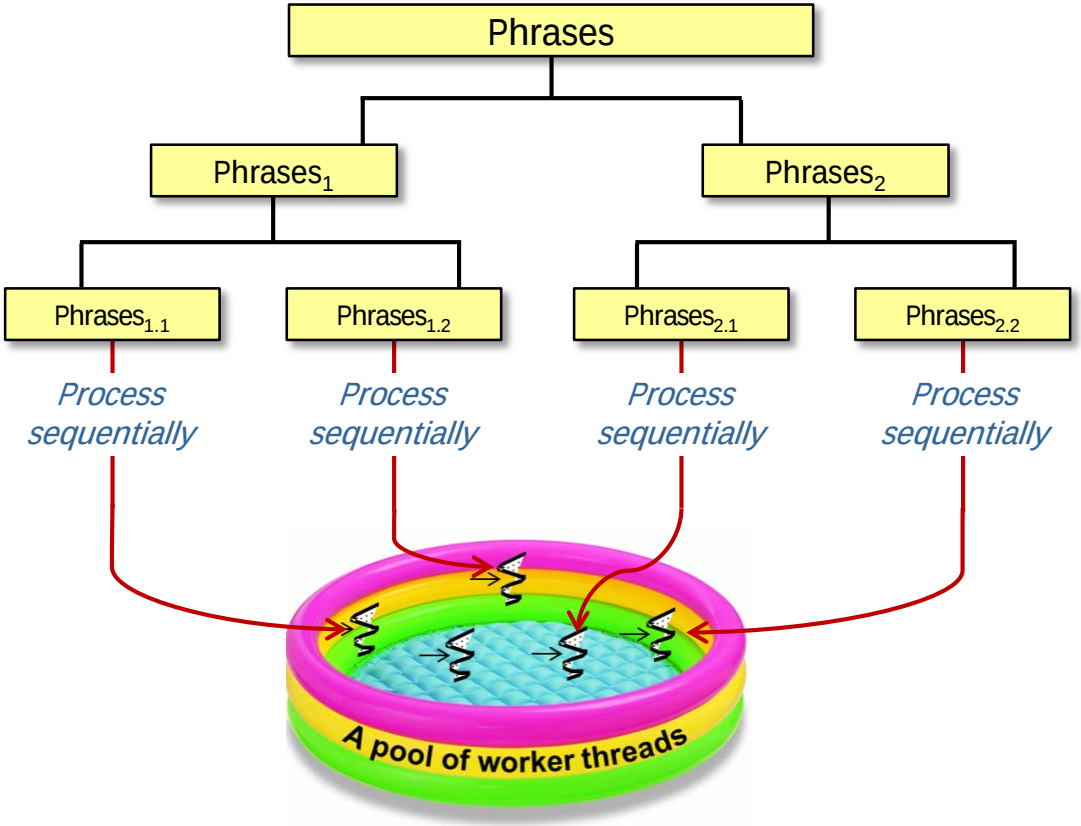
Overview of SearchWithParallelSpliterator

- SearchWithParallelSpliterator uses parallel streams in three ways
  - Search chunks of phrases concurrently



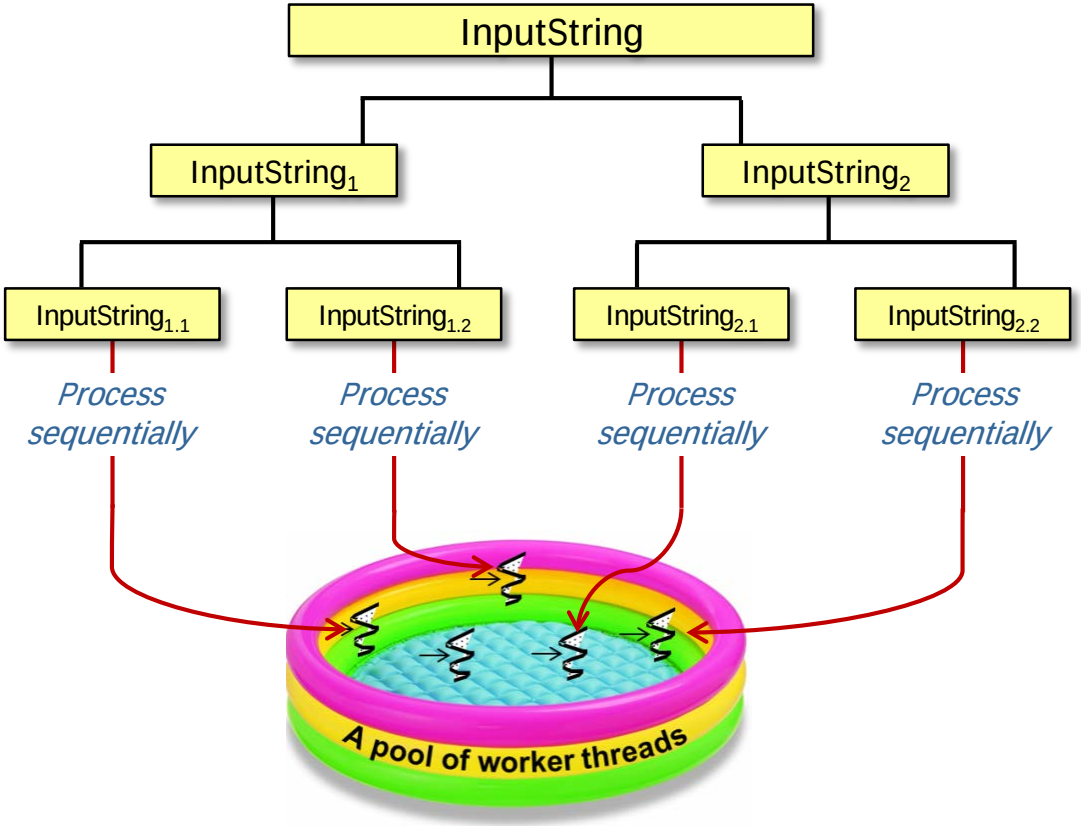
Overview of SearchWithParallelSpliterator

- SearchWithParallelSpliterator uses parallel streams in three ways
  - Search chunks of phrases concurrently
  - Search chunks of input concurrently



Overview of SearchWithParallelSpliterator

- SearchWithParallelSpliterator uses parallel streams in three ways
  - Search chunks of phrases concurrently
  - Search chunks of input concurrently
  - Search chunks of each input string concurrently



Overview of SearchWithParallelSpliterator

- SearchWithParallelSpliterator uses parallel streams in three ways
  - Search chunks of phrases concurrently
  - Search chunks of input concurrently
  - Search chunks of each input string concurrently

SearchWithParallelSpliterator is thus the most aggressively concurrent strategy!

Overview of SearchWithParallelSpliterator

- The relative contribution of each parallel streams model is shown here:

Time for 38 strings = 703 ms (parallelSpliterator|parallelPhrases|parallelInput)

Time for 38 strings = 706 ms (sequentialSpliterator|parallelPhrases|parallelInput)

Time for 38 strings = 726 ms (parallelSpliterator|sequentialPhrases|parallelInput)

Time for 38 strings = 739 ms (sequentialSpliterator|sequentialPhrases|parallelInput)

Time for 38 strings = 749 ms (sequentialSpliterator|parallelPhrases|sequentialInput)

Time for 38 strings = 759 ms (parallelSpliterator|parallelPhrases|sequentialInput)

Time for 38 strings = 1760 ms (parallelSpliterator|sequentialPhrases|sequentialInput)

Time for 38 strings = 3000 ms(sequentialSpliterator|sequentialPhrases|sequentialInput)

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

Overview of SearchWithParallelSpliterator

- Longer input strings leverage the parallel spliterator even better:

Time for 2 strings = 700 ms (parallelSpliterator|parallelPhrases|parallelInput)

Time for 2 strings = 738 ms (parallelSpliterator|parallelPhrases|sequentialInput)

Time for 2 strings = 761 ms (sequentialSpliterator|parallelPhrases|parallelInput)

Time for 2 strings = 780 ms (sequentialSpliterator|parallelPhrases|sequentialInput)

Time for 2 strings = 1008 ms (parallelSpliterator|sequentialPhrases|parallelInput)

Time for 2 strings = 1617 ms (parallelSpliterator|sequentialPhrases|sequentialInput)

Time for 2 strings = 1986 ms (sequentialSpliterator|sequentialPhrases|parallelInput)

Time for 2 strings = 2870 ms (sequentialSpliterator|sequentialPhrases|sequentialInput)

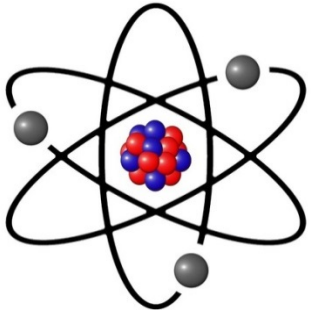
Overview of SearchWithParallelSpliterator

- SearchWithParallelSpliterator processInput() has just one minuscule change

```
List<SearchResults> processInput(CharSequence inputSeq) {
  String title = getTitle(inputString);
  CharSequence input = inputSeq.subSequence(...);

  List<SearchResults> results = mPhrasesToFind
    .parallelStream()
    .map(phase ->
         searchForPhrase(phase, input, title, true))
    .filter(not(SearchResults::isEmpty))

    .collect(toList());
  return results;
}
```



The value of "true" triggers the use of a parallel search for a phrase in an input string

Overview of SearchWithParallelSpliterator

- searchForPhrase() uses a parallel spliterator to break the input into “chunks” that are processed in parallel

```
SearchResults searchForPhrase(String phrase, CharSequence input,
                              String title, boolean parallel) {
  return new SearchResults
    (..., ..., phrase, title, StreamSupport
     .stream(new PhraseMatchSpliterator(input, phrase),
             parallel)
     .collect(toList()));
}
```

See SearchStreamGang/src/main/java/livelessons/streamgangs/SearchStreamGang.java

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     .stream(new PhraseMatchSpliterator(input, phrase),
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     .collect(toList()));
  }
```

StreamSupport.stream() creates a sequential or parallel stream via PhraseMatchSpliterator

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

Overview of SearchWithParallelSpliterator

- searchForPhrase() uses a parallel spliterator to break the input into "chunks" that are processed in parallel

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     .collect(toList()));
  }
```

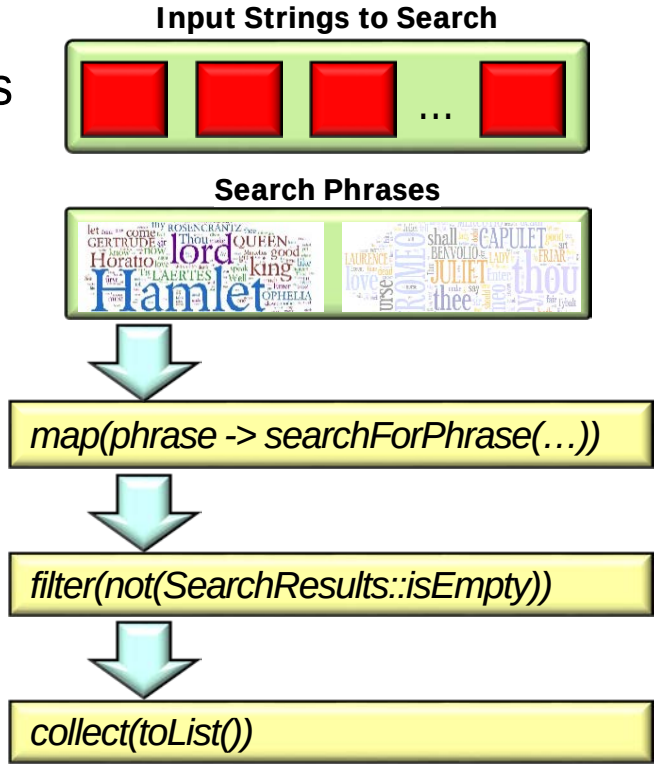
The value of "parallel" is true when searchForPhrase() is called in the SearchWithParallelSpliterator program

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

Using Parallel Spliterator in SearchStreamGang

Using a Parallel Spliterator in SearchStreamGang

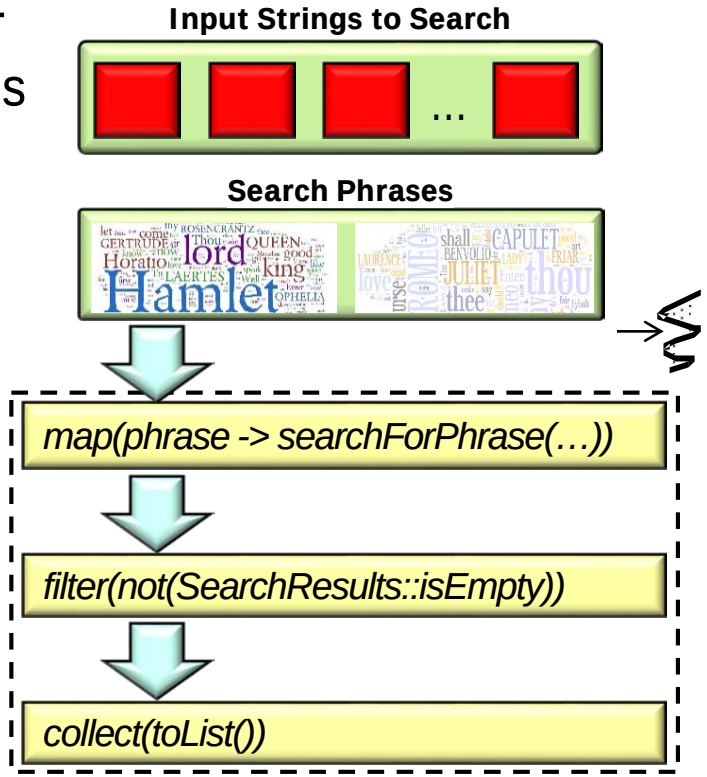
- SearchStreamGang uses PhraseMatchSpliterator that works for both sequential & parallel streams



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

Using a Parallel Spliterator in SearchStreamGang

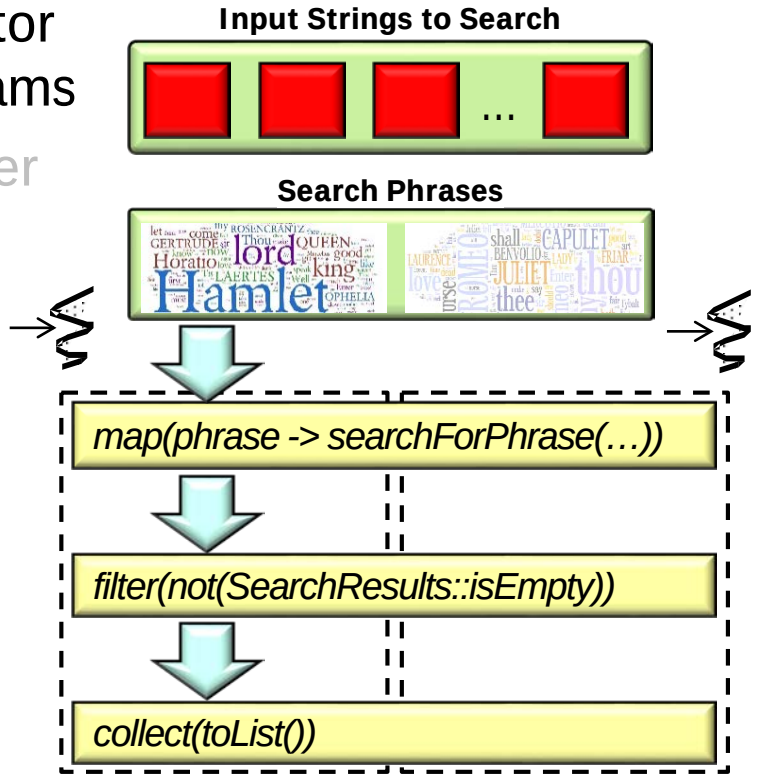
- SearchStreamGang uses PhraseMatchSpliterator that works for both sequential & parallel streams
  - We focused on the sequential portions earlier



See *"Java 8 Sequential SearchStreamGang Example (Part 2)"*

Using a Parallel Spliterator in SearchStreamGang

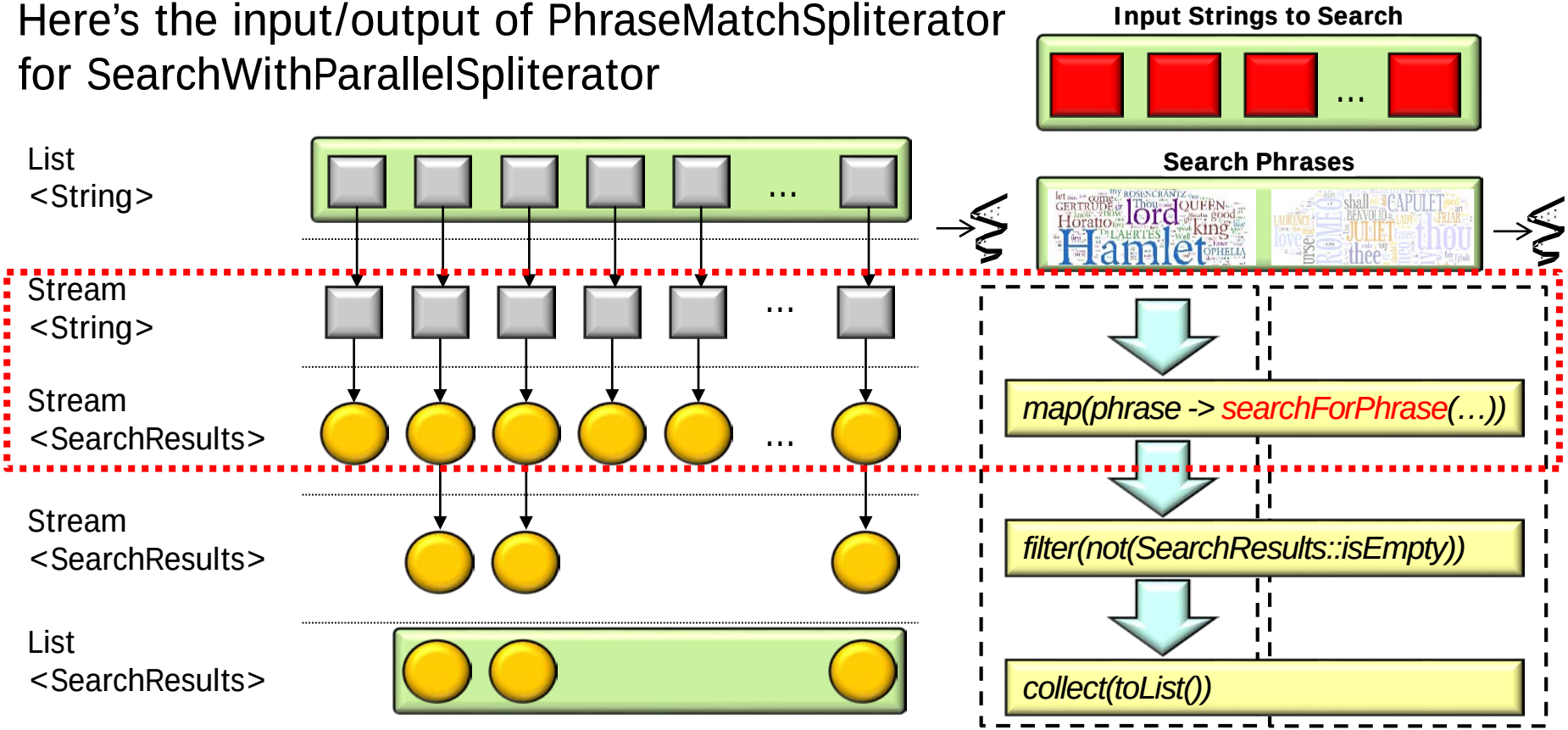
- SearchStreamGang uses PhraseMatchSpliterator that works for both sequential & parallel streams
  - We focused on the sequential portions earlier
  - We'll cover the parallel portions now



The goal is to further optimize the performance of the parallel streams solution

Using a Parallel Spliterator in SearchStreamGang

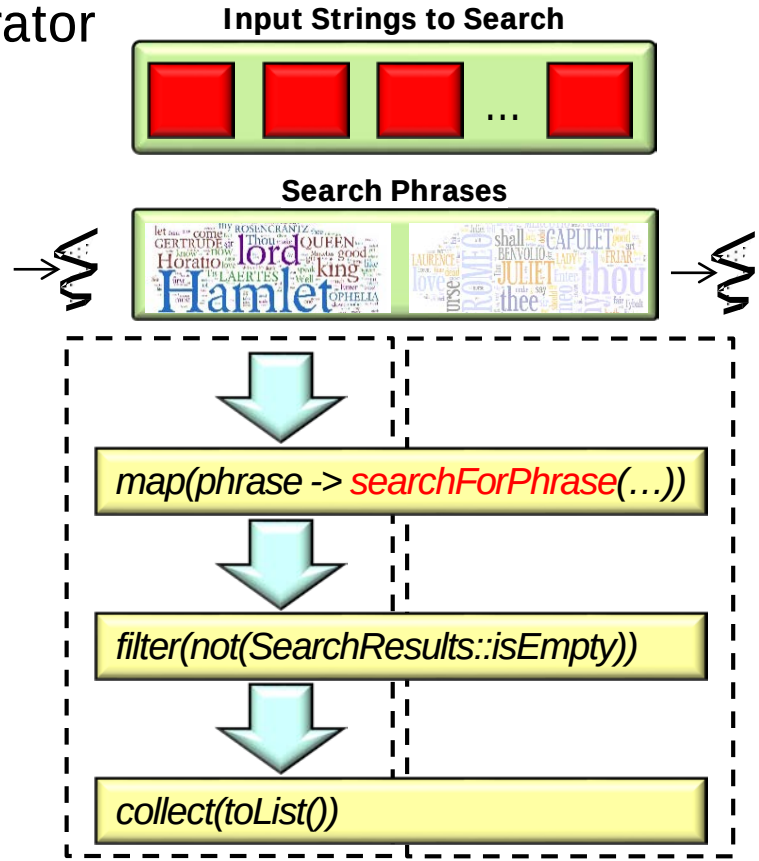
- Here's the input/output of PhraseMatchSpliterator for SearchWithParallelSpliterator



Using a Parallel Spliterator in SearchStreamGang

- Here's the input/output of PhraseMatchSpliterator for SearchWithParallelSpliterator

"…
My liege, and madam, to expostulate
What majesty should be, what duty is,
Why day is day, night is night, and time is time.
Were nothing but to waste night, day, and time.
Therefore, since brevity is the soul of wit,
And tediousness the limbs and outward flourishes,
I will be brief. Your noble son is mad.
Mad call I it; for, to define true madness,
What is't but to be nothing else but mad?
But let that go…."



This spliterator splits the input into multiple chunks & searches them in parallel

Using a Parallel Spliterator in SearchStreamGang

- Here's the input/output of PhraseMatchSpliterator for SearchWithParallelSpliterator

"Brevity is the soul of wit" at [54739]

"…
My liege, and madam, to expostulate
What majesty should be, what duty is,
Why day is day, night is night, and time is time.
Were nothing but to waste night, day, and time.
Therefore, since brevity is the soul of wit,"

"And tediousness the limbs and outward flourishes,
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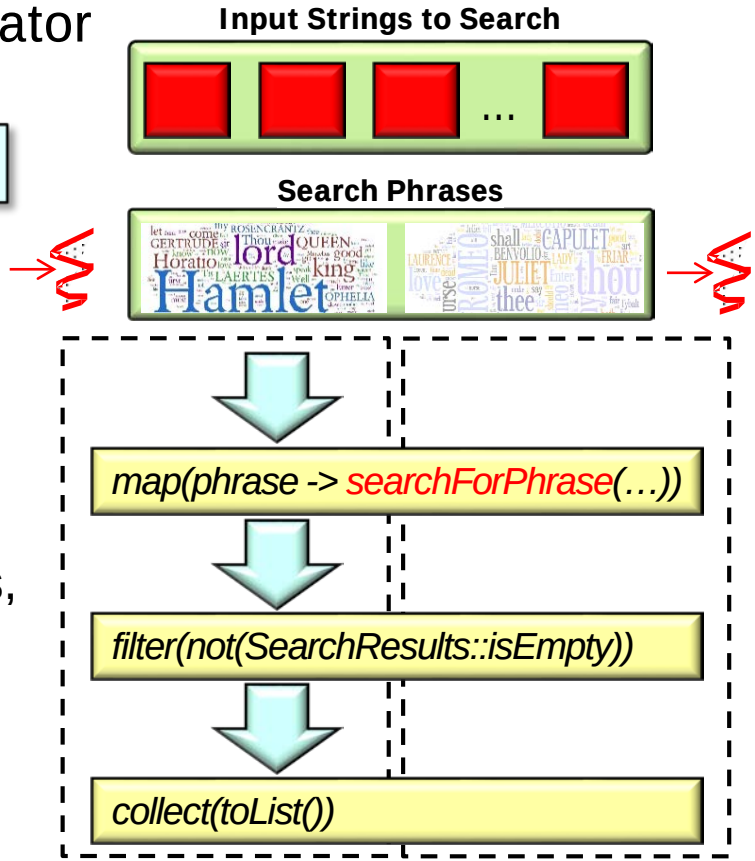
What is't but to be nothing else but mad?
But let that go...."



When the split occurs efficiently/evenly the speedups can be substantial!

Using a Parallel Spliterator in SearchStreamGang

- Here's the input/output of PhraseMatchSpliterator for SearchWithParallelSpliterator

"Brevity is the soul of wit" not found!

"…
My liege, and madam, to expostulate
What majesty should be, what duty is,
Why day is day, night is night, and time is time.
Were nothing but to waste night, day, and time.
Therefore, since brevity is the soul of"

"wit, And tediousness the limbs and outward
flourishes, I will be brief. Your noble son is mad.
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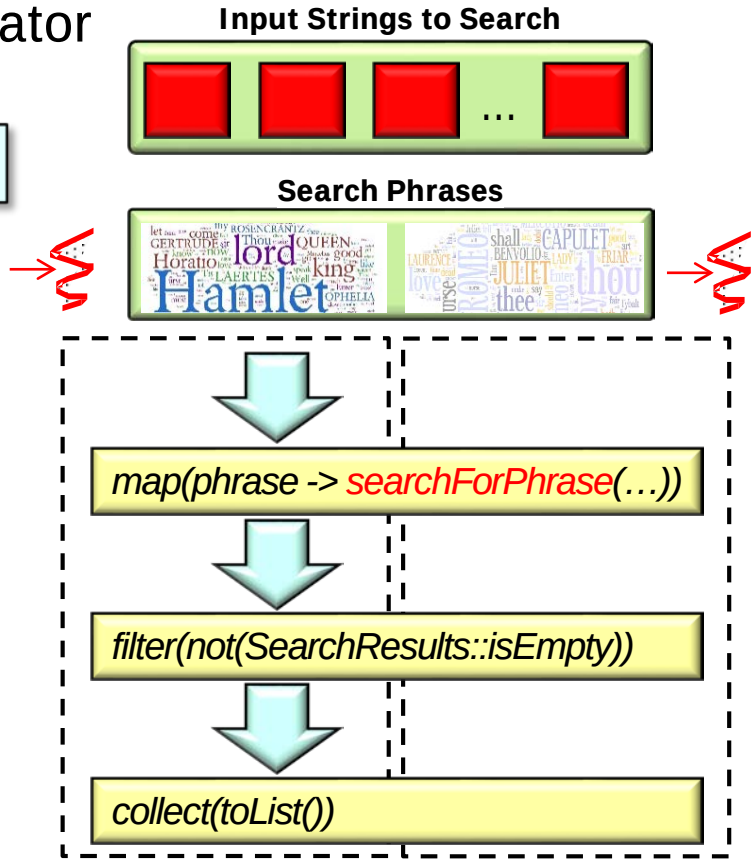
What is't but to be nothing else but mad?
But let that go...."



However, the spliterator must be careful not to split input *across* phrases...

Using a Parallel Spliterator in SearchStreamGang

- PhraseMatchSpliterator uses Java regex to create a stream of SearchResults Result objects that match the # of times a phrase appears in an input string

```
class PhraseMatchSpliterator implements Spliterator<Result> {
  ...
  PhraseMatchSpliterator
    (CharSequence input,
     String phrase) { ... }

  boolean tryAdvance
    (Consumer<? super Result> action)
  { ... }
  ...
```

Spliterator is an interface that defines eight methods, including tryAdvance() & trySplit()

See SearchStreamGang/src/main/java/livelessons/utils/PhraseMatchSpliterator.java

Using a Parallel Spliterator in SearchStreamGang

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class PhraseMatchSpliterator implements Spliterator<Result> {
  ...
  PhraseMatchSpliterator(CharSequence input,
                         String phrase) { ... }

  boolean tryAdvance(Consumer<? super Result> action) { ... }
  ...
```

Earlier we analyzed several of its methods that are used in sequential streams

See *"Java 8 Sequential SearchStreamGang Example (Part 2)"*

Using a Parallel Spliterator in SearchStreamGang

- PhraseMatchSpliterator uses Java regex to create a stream of SearchResults Result objects that match the # of times a phrase appears in an input string

```
class PhraseMatchSpliterator implements Spliterator<Result> {
  ...
  Spliterator<Result> trySplit() { ... }

  int computeStartPos(int splitPos) { ... }

  int tryToUpdateSplitPos(int startPos, int splitPos) { ... }

  PhraseMatchSpliterator splitInput(int splitPos) { ... }

  ...
```

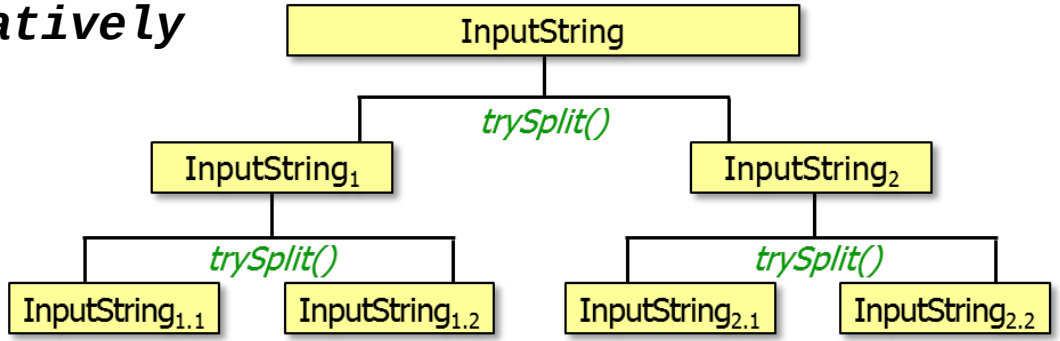
We'll now explore its methods that are used for parallel streams

Note that there is *no* synchronization in any of these methods!!!

Using a Parallel Spliterator in SearchStreamGang

- PhraseMatchSpliterator uses Java regex to create a stream of SearchResults Result objects that match the # of times a phrase appears in an input string

```
class PhraseMatchSpliterator implements Spliterator<Result> {
  ...
  Spliterator<Result> trySplit() {
    if (input is below minimum size) return null
    else {
      split input in 2 relatively
        even-sized chunks
      return a spliterator
        for "left chunk"
    }
  }
  ...
```



trySplit() attempts to split the input "evenly so phrases can be matched in parallel

Using a Parallel Spliterator in SearchStreamGang

- PhraseMatchSpliterator uses Java regex to create a stream of SearchResults Result objects that match the # of times a phrase appears in an input string

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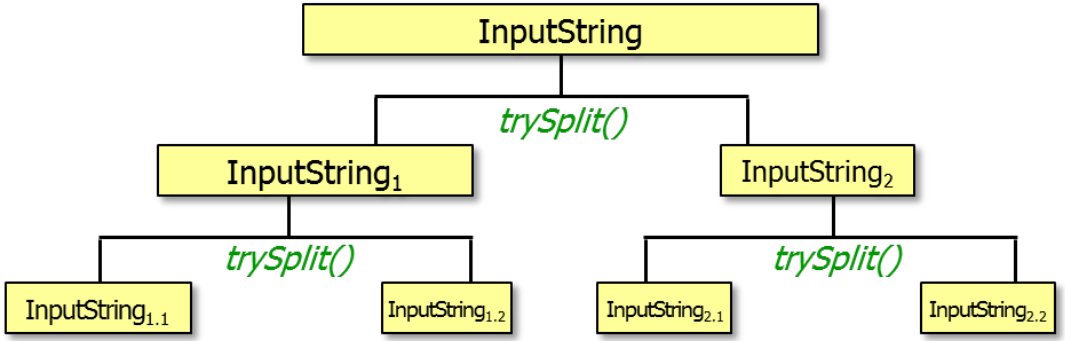


Splits don't needn't be perfectly equal in order for the spliterator to be efficient

Using a Parallel Spliterator in SearchStreamGang

- PhraseMatchSpliterator uses Java regex to create a stream of SearchResults Result objects that match the # of times a phrase appears in an input string

```
class PhraseMatchSpliterator implements Spliterator<Result> {
  ...
  Spliterator<Result> trySplit() {
    if (mInput.length() <= mMinSplitSize) return null;

    int startPos, splitPos = mInput.length() / 2;

    if ((startPos = computeStartPos(splitPos)) < 0) return null;

    if ((splitPos = tryToUpdateSplitPos(startPos, splitPos)) < 0)
      return null;

    return splitInput(splitPos); ...
```

This code is complicated since it doesn't split a string across a phrase

This code is highly commented, so please have a look at it (we may cover it later)

Using a Parallel Spliterator in SearchStreamGang

- PhraseMatchSpliterator uses Java regex to create a stream of SearchResults Result objects that match the # of times a phrase appears in an input string

```
class PhraseMatchSpliterator implements Spliterator<Result> {
  ...
  Spliterator<Result> splitInput(int splitPos) {
    CharSequence seq = mInput.subSequence(0, splitPos);

    mInput = mInput.subSequence(splitPos, mInput.length());

    mPhraseMatcher = mPattern.matcher(mInput);

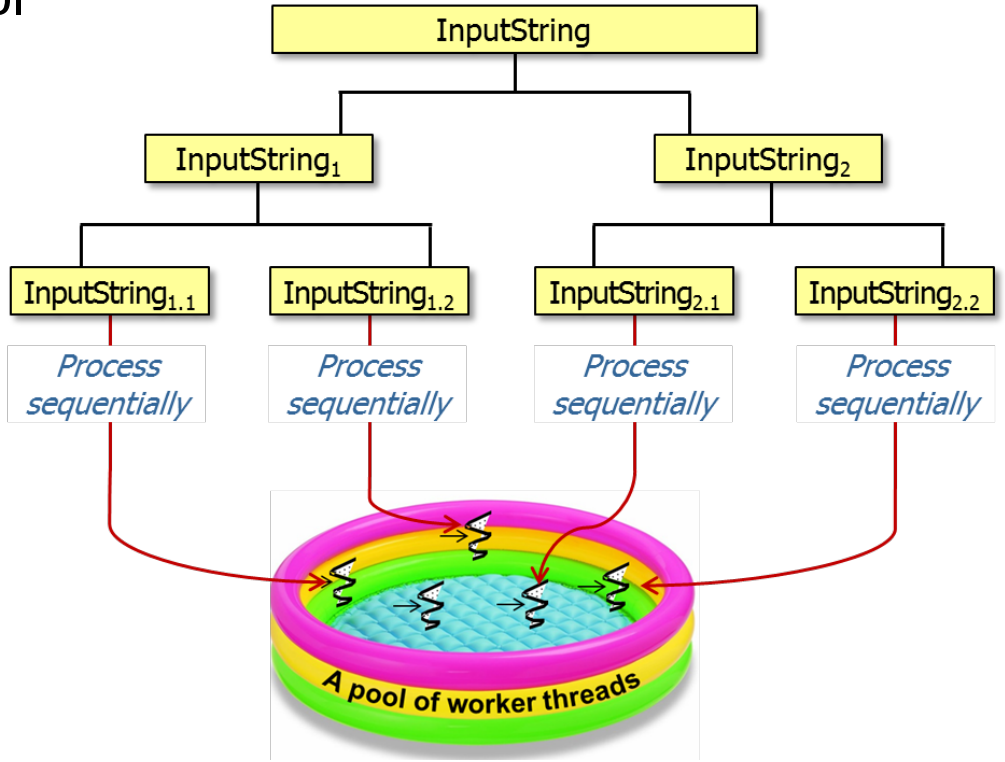
    ...

    return new PhraseMatchSpliterator(seq, ...); ...
```

Return a Spliterator that handles "left hand" portion of input, while "this" object handles "right hand" portion of input

Using a Parallel Spliterator in SearchStreamGang

- The Java 8 parallel streams runtime processes all the spliterator chunks in parallel in the common fork-join pool



This parallelism is in addition to parallelism of input string & phrase chunks!!

Pros of the SearchWith ParallelSpliterator Class

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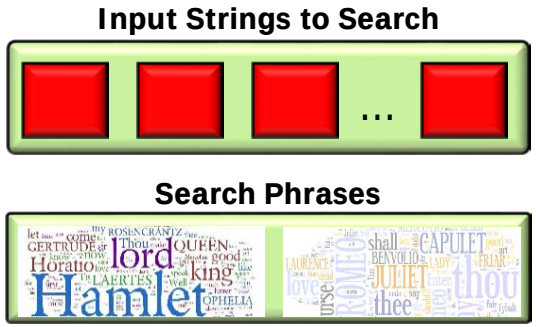
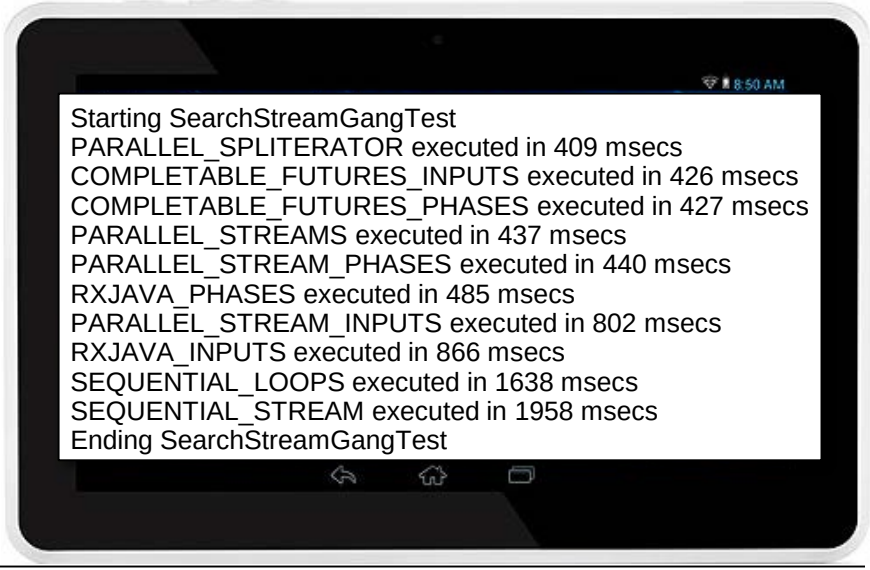
- This example shows how a parallel spliterator can help transparently improve program performance





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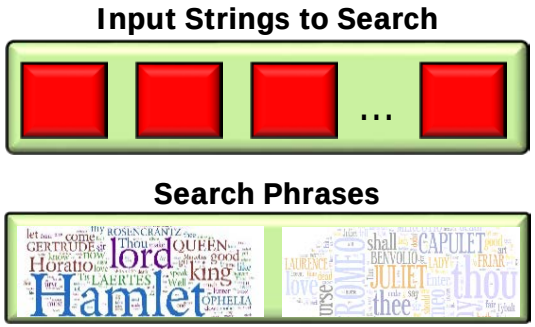

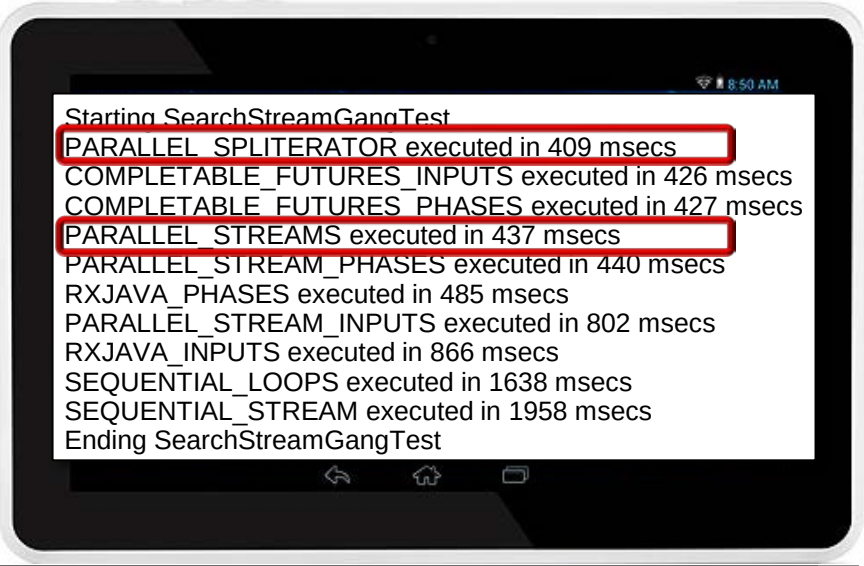

Tests conducted on a 2.7GHz quad-core Lenovo P50 with 32 Gbytes of RAM

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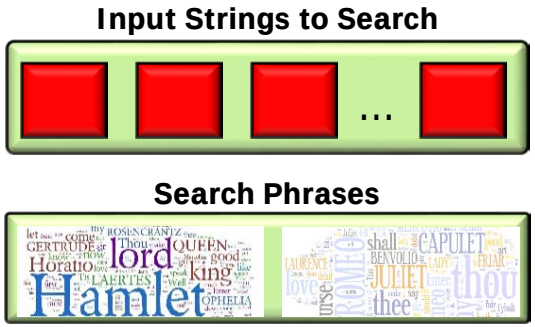
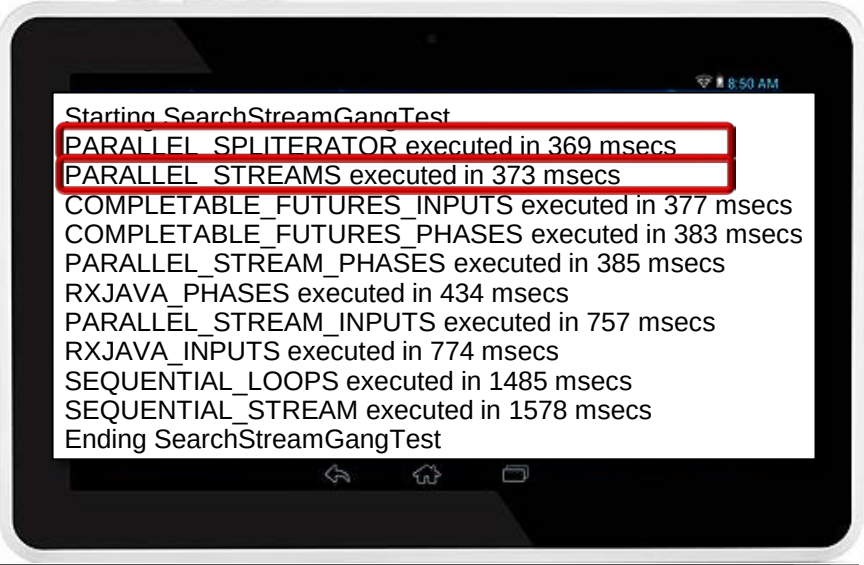
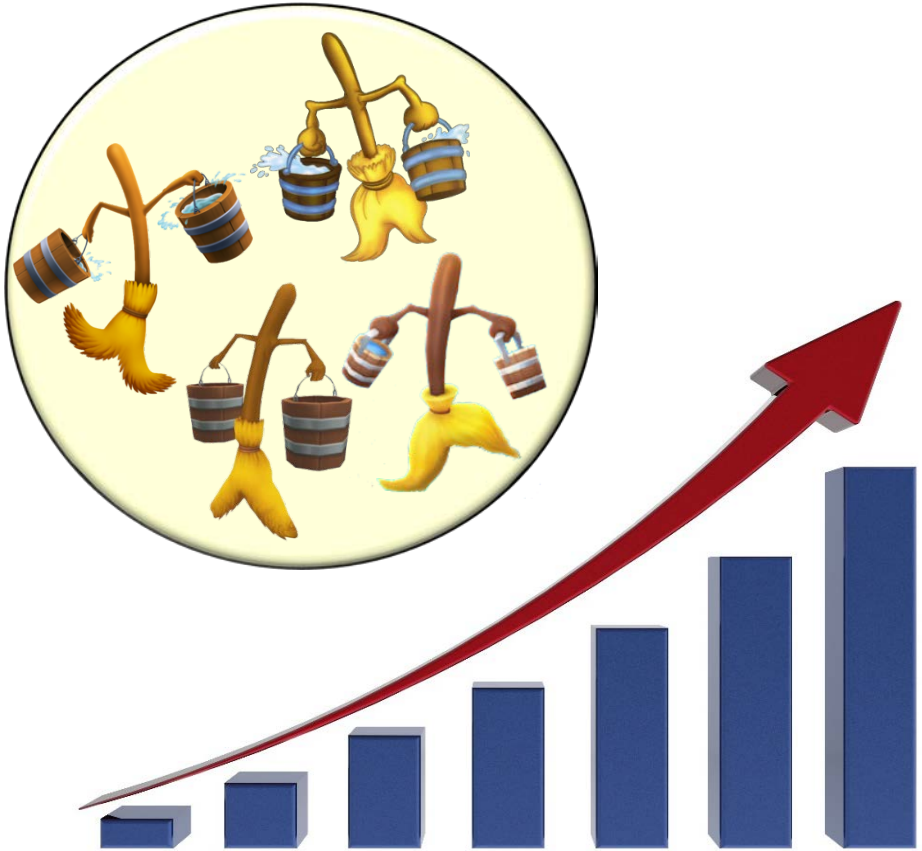




Tests conducted on a 2.9GHz quad-core MacBook Pro with 16 Gbytes of RAM

Pros of the SearchWithParallelSpliterator Class

- This example shows how a parallel spliterator can help transparently improve program performance
  - These speedups occur since the granularity of parallelism is smaller & thus better able to leverage available cores



See docs.oracle.com/javase/tutorial/collections/streams/parallelism.html

Pros of the SearchWithParallelSpliterator Class

- This example also shows that the difference between using sequential vs parallel spliterator can be minuscule!

```
SearchResults searchForPhrase(String phrase, CharSequence input,
                              String title, boolean parallel) {
  return new SearchResults
    (..., ..., phrase, title, StreamSupport
     .stream(new PhraseMatchSpliterator(input,
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     .collect(toList()));
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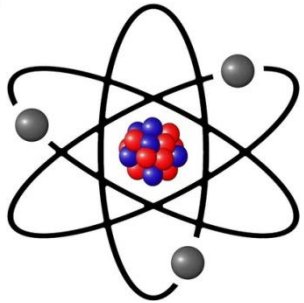
```



Switching this boolean from "false" to "true" controls whether the spliterator runs sequentially or in parallel

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             parallel)
     .collect(toList()));
}
```

Of course, it took non-trivial time/effort to create PhraseMatchSpliterator..

Cons of the SearchWith ParallelSpliterator Class

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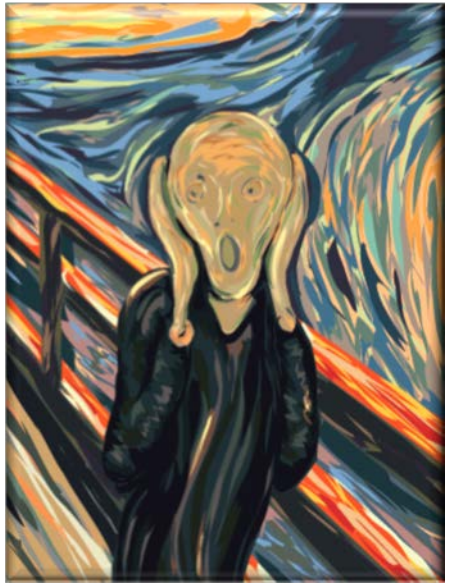
- The parallel-related portions of PhraseMatchSpliterator are *much* more complicated to program than the sequential-related portions...

```
class PhraseMatchSpliterator
      implements Spliterator<Result> {
  ...
  Spliterator<Result> trySplit() { ... }

  int computeStartPos(int splitPos) { ... }

  int tryToUpdateSplitPos(int startPos,
                          int splitPos)
    { ... }

  PhraseMatchSpliterator splitInput(int splitPos) { ... }
  ...
```



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                          int splitPos)
    { ... }

  PhraseMatchSpliterator splitInput(int splitPos) { ... }
  ...
```

Must split carefully..

JUnit

Junit tests are extremely useful..

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      implements Spliterator<Result> {
  ...
  Spliterator<Result> trySplit() { ... }

  int computeStartPos(int splitPos) { ...

  int tryToUpdateSplitPos(int startPos,
                          int splitPos)
    { ... }

  PhraseMatchSpliterator splitInput(int splitPos) { ... }
  ...
```

Writing the parallel spliterator took longer than writing the rest of the program!

End of Java 8 Parallel SearchStreamGang Example (Part 2)