The Java Fork-Join Pool: Implementing applyAllSplit()

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Learning Objectives in this Part of the Lesson

- Apply the fork-join framework in practice
- Examine the applyAllIter() method
- Examine the applyAllSplit() method

```
<T> List<T> applyAllSplit
  (List<T> list,
   Function<T, T> op,
   ForkJoinPool fjPool) {
   class SplitterTask
   extends RecursiveTask
     <List<T>> { ... }

  return fjPool
    .invoke(new
       SplitterTask(list));
}
```

See github.com/douglascraigschmidt/LiveLessons/tree/master/Java8/ex22

Implementing the Method applyAllSplit()

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- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
<T> List<T> applyAllSplit(List<T> list, Function<T, T> op,
                          ForkJoinPool fjPool) {
  class SplitterTask extends RecursiveTask<List<T>> { ... }

  return fjPool
    .invoke(new SplitterTask(list));
}
```

See LiveLessons/blob/master/Java8/ex22/src/utils/ForkJoinUtils.java

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
<T> List<T> applyAllSplit(List<T> list, Function<T, T> op,
                          ForkJoinPool fjPool) {
  class SplitterTask extends RecursiveTask<List<T>> { ... }

  return fjPool
    .invoke(new SplitterTask(list));
}
```

This task recursively partitions the list & runs each half in a ForkJoinTask

This use case is an ideal application of the fork-join framework!

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
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  class SplitterTask extends RecursiveTask<List<T>> { ... }
```


```
  return fjPool
    .invoke(new SplitterTask(list));
}
```

Invoke a new SplitterTask in the fork-join pool & then wait for & return the results

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
<T> List<T> applyAllSplit(List<T> list, Function<T, T> op,
                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
    private List<T> mList;

    private SplitterTask(List<T> list) {
        mList = list;
    }
    ...

  } ...
```

This implementation recursively splits the list evenly in half & copies data

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
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  class SplitterTask extends RecursiveTask<List<T>> {
    private List<T> mList;

    private SplitterTask(List<T> list) {
        mList = list;
    }
    ...

  } ...
```

Constructor stores a reference to a portion of the original list

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
<T> List<T> applyAllSplit(List<T> list, Function<T, T> op,
                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
    protected List<T> compute() {
      if (mList.size() <= 1) {
        List<T> result =
          new ArrayList<>();

        for (T t : mList) result.add(op.apply(t));

        return result;
      } else {
        ...
    } ...
```

Recursively perform the computations in parallel on a subset of the list

Implementing the Method applyAllSplit()

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      if (mList.size() <= 1) {
        List<T> result =
          new ArrayList<>();

        for (T t : mList) result.add(op.apply(t));

        return result;
      } else {
        ...
    } ...
```

If the list has 1 or 0 elements create an empty ArrayList

This if statement handles the base case for the recursion

Implementing the Method applyAllSplit()

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      if (mList.size() <= 1) {
        List<T> result =
          new ArrayList<>();

        for (T t : mList) result.add(op.apply(t));

        return result;
      } else {
        ...
    } ...
```

Apply op to the element in this list & add it to the result list

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
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      if (mList.size() <= 1) {
        List<T> result =
          new ArrayList<>();

        for (T t : mList) result.add(op.apply(t));

        return result;
      } else {
        ...
    } ...
```

Return the result list

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
<T> List<T> applyAllSplit(List<T> list, Function<T, T> op,
                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
    protected List<T> compute() {
      ... else {
        int mid = mList.size() / 2;
        ForkJoinTask<List<T>> lt =
          new SplitterTask(mList.subList(0, mid)).fork();
        mList = mList.subList(mid, mList.size());
        List<T> rightResult = compute();
        List<T> leftResult = lt.join();
        leftResult.addAll(rightResult);
        return leftResult;
    } ...
```

Determine mid-point of the list

This else statement recursively & evenly partitions the list

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
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                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
    protected List<T> compute() {
      ... else {
        int mid = mList.size() / 2;
        ForkJoinTask<List<T>> lt =
          new SplitterTask(mList.subList(0, mid)).fork();
        mList = mList.subList(mid, mList.size());
        List<T> rightResult = compute();
        List<T> leftResult = lt.join();
        leftResult.addAll(rightResult);
        return leftResult;
    } ...
```

Create a new task to handle left-side of the list & fork it

This recursive decomposition disperses tasks to (other) worker threads

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
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                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
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      ... else {
        int mid = mList.size() / 2;
        ForkJoinTask<List<T>> lt =
          new SplitterTask(mList.subList(0, mid)).fork();
        mList = mList.subList(mid, mList.size());
        List<T> rightResult = compute();
        List<T> leftResult = lt.join();
        leftResult.addAll(rightResult);
        return leftResult;
    } ...
```

Update mList to handle the right-side & compute results

compute() runs in the same task as its "parent" to minimize context switching

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
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                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
    protected List<T> compute() {
      ... else {
        int mid = mList.size() / 2;
        ForkJoinTask<List<T>> lt =
          new SplitterTask(mList.subList(0, mid)).fork();
        mList = mList.subList(mid, mList.size());
        List<T> rightResult = compute();
        List<T> leftResult = lt.join();
        leftResult.addAll(rightResult);
        return leftResult;
    } ...
```

Join with left-side results

compute() must be called before join()!

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

```
<T> List<T> applyAllSplit(List<T> list, Function<T, T> op,
                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
    protected List<T> compute() {
      ... else {
        int mid = mList.size() / 2;
        ForkJoinTask<List<T>> lt =
          new SplitterTask(mList.subList(0, mid)).fork();
        mList = mList.subList(mid, mList.size());
        List<T> rightResult = compute();
        List<T> leftResult = lt.join();
        leftResult.addAll(rightResult);
        return leftResult;
    } ...
```

Combine left- & right-size & return results

Data may be copied since these the lists are implemented via ArrayList

Implementing the Method applyAllSplit()

- Apply an 'op' to all list items by recursively splitting via fork-join method calls

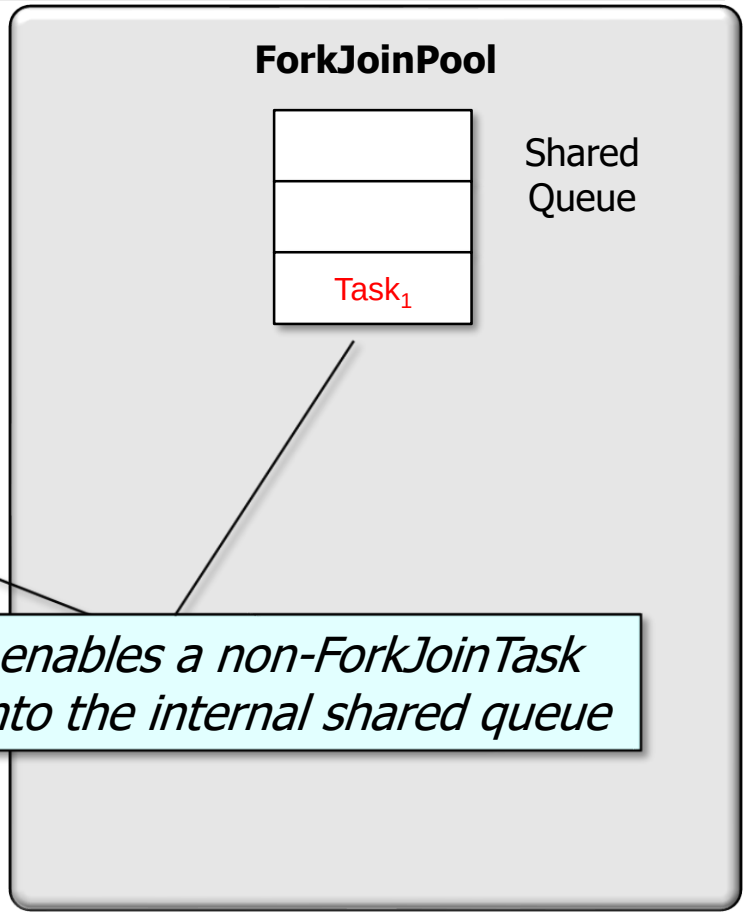
```
<T> List<T> applyAllSplit(List<T> list, Function<T, T> op,
                          ForkJoinPool fjPool) { ...
  class SplitterTask extends RecursiveTask<List<T>> {
    protected List<T> compute() {
      ... else {
        int mid = mList.size() / 2;
        ForkJoinTask<List<T>> lt =
          new SplitterTask(mList.subList(0, mid)).fork();
        mList = mList.subList(mid, mList.size());
        List<T> rightResult = compute();
        List<T> leftResult = lt.join();
        leftResult.addAll(rightResult);
        return leftResult;
    } ...
```

This implementation is harder to program & understand since it's recursive

Implementing the Method applyAllSplit()

- Visualizing applyAllSplit()

```
<T> List<T> applyAllSplit
          (List<T> list,
           Function<T, T> op,
           ForkJoinPool fjPool) {
  ...
  return fjPool
    .invoke(new SplitterTask
                (list));
}
```



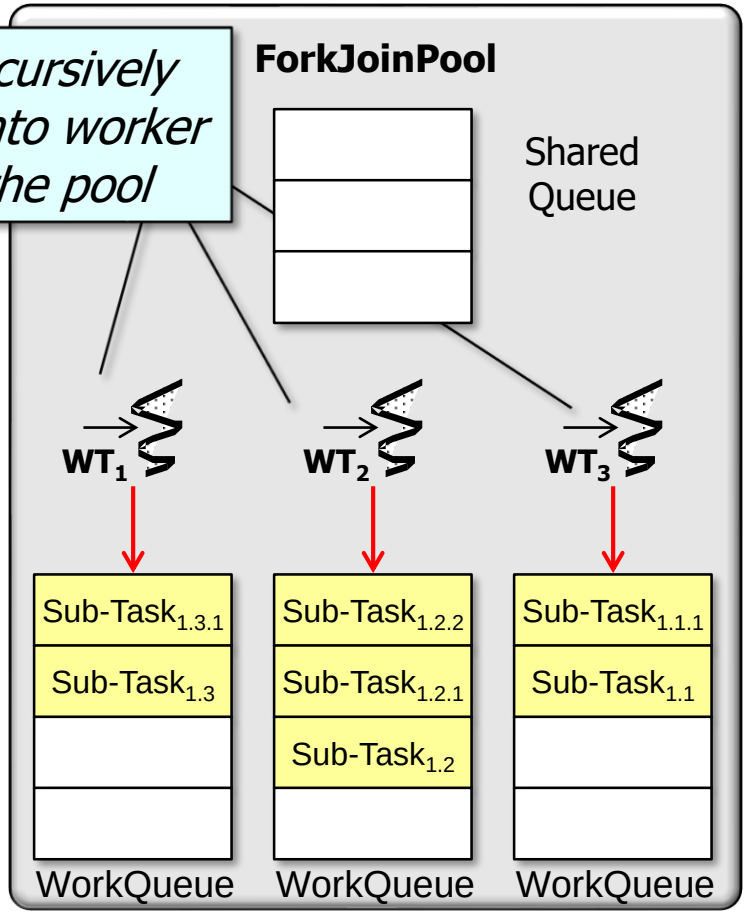
The invoke() method enables a non-ForkJoinTask client to insert a task into the internal shared queue

Implementing the Method applyAllSplit()

- Visualizing applyAllSplit()

```
<T> List<T> applyAllSplit
          (List<T> list,
           Function<T, T> op,
           ForkJoinPool fjPool) { ...
 class SplitterTask ... {
    protected List<T> compute() {
       ... else {
         ForkJoinTask<List<T>> lt =
           new SplitterTask
             (mList.subList(0, mid))
           .fork();
         ...
         List<T> rightResult =
           compute(); ...
```

Sub-tasks recursively decompose onto worker threads in the pool



"Work-stealing" overhead is lower, but copying & method call overhead is higher

Implementing the Method applyAllSplit()

- Visualizing applyAllSplit()

```
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          (List<T> list,
           Function<T, T> op,
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 class SplitterTask ... {
    protected List<T> compute() {
       ... else {
         ForkJoinTask<List<T>> lt =
           new SplitterTask
             (mList.subList(0, mid))
           .fork();
         ...
         List<T> rightResult =
           compute(); ...
```
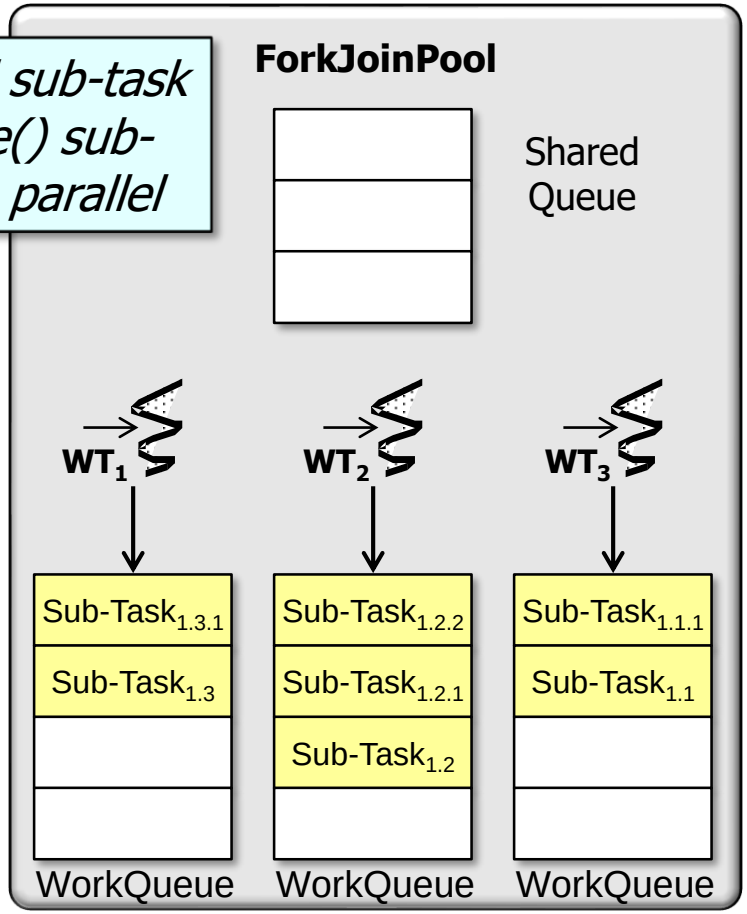

The fork()'d sub-task & compute() sub-task run in parallel



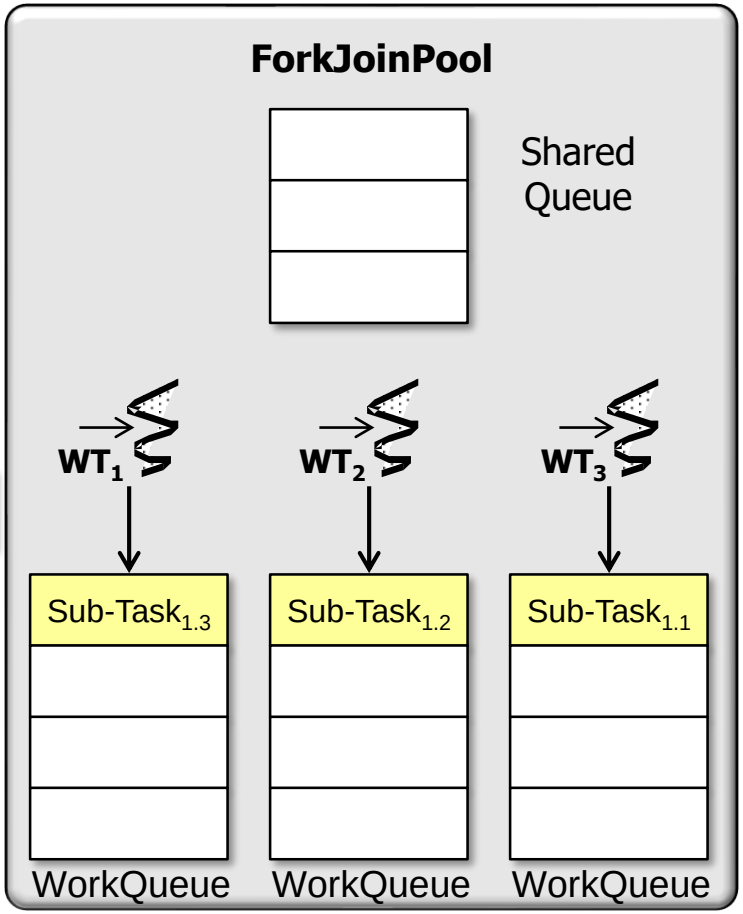
compute() runs in the same task as its "parent" to optimize performance

Implementing the Method applyAllSplit()

- Visualizing applyAllSplit()

```
<T> List<T> applyAllSplit
          (List<T> list,
           Function<T, T> op,
           ForkJoinPool fjPool) { ...
 class SplitterTask ... {
    protected List<T> compute() {
       ... else {
          ...
          List<T> leftResult =
            lt.join();
          leftResult
            .addAll(rightResult);
          return leftResult;
       }
```

join() returns a value



There is a "balanced tree" of join() calls, which scales better than applyAllIter()

End of the Java Fork-Join Pool: Implementing applyAllSplit()