Professional Programming in Java

Session: 13

Advanced Concurrency and Parallelism

Objectives

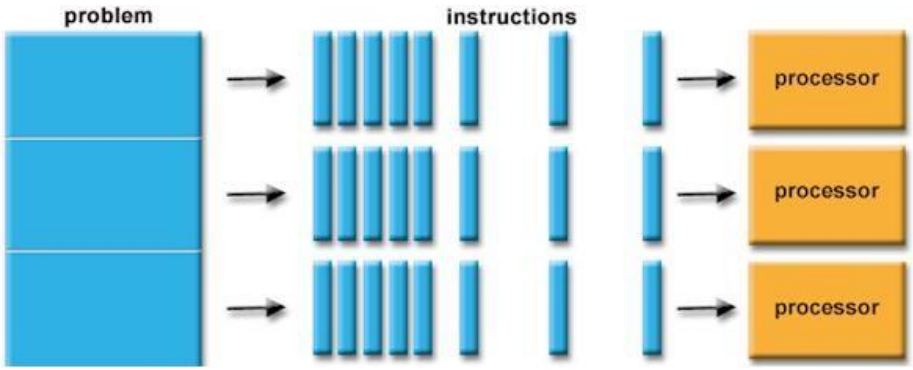
- Explain the enhancements of **java.util.concurrency** package
- Describe atomic operations with the new set of classes of the **java.util.concurrent.atomic** package
- Explain the **StampedLock** class to implement locks
- Explain the new features of **ForkJoinPool**
- Define parallel streams
- Describe parallel sorting of arrays
- Identify recursive actions of the fork/join framework

Introduction [1-2]

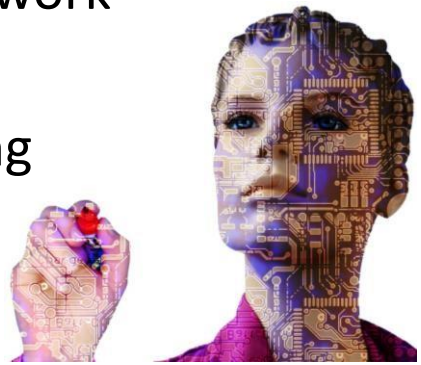
- Similar to tasks that run in parallel in real world, parallelization refers to the process of taking a serial code that runs on a single CPU and spreading the work across multiple CPUs.

Introduction [2-2]

- An important enhancement in Java programming language is parallelization.



- Parallelization is used to make applications run efficiently.
- Challenges faced by parallelism are addressed through work stealing strategy.
- The Fork-Join framework in Java meets the work stealing requirements through recursive job partitioning.



New Enhancements in the java.util.concurrent Package

- Many new enhancements have been made to the **`java.util.concurrency`** package

Classes

- `CompletableFuture`
- `CountedCompletor`
- `ConcurrentHashMap.KeySetView`

Interface

- `CompletableFuture.AsynchronousCompletionTask`
- `CompletionStage<T>`

Exception

- `CompletionException`

CompletableFuture Class [1-2]

- The class implements the **`CompletionStage`** and the **`Future`** interface to simplify asynchronous operations.
- An existing **`Future`** interface represents the result of an asynchronous computation.
- The **`get()`** method of the F**`uture`** interface returns the result of the computation.
- The methods of the **`CompletableFuture`** class run asynchronously without stopping the program execution.

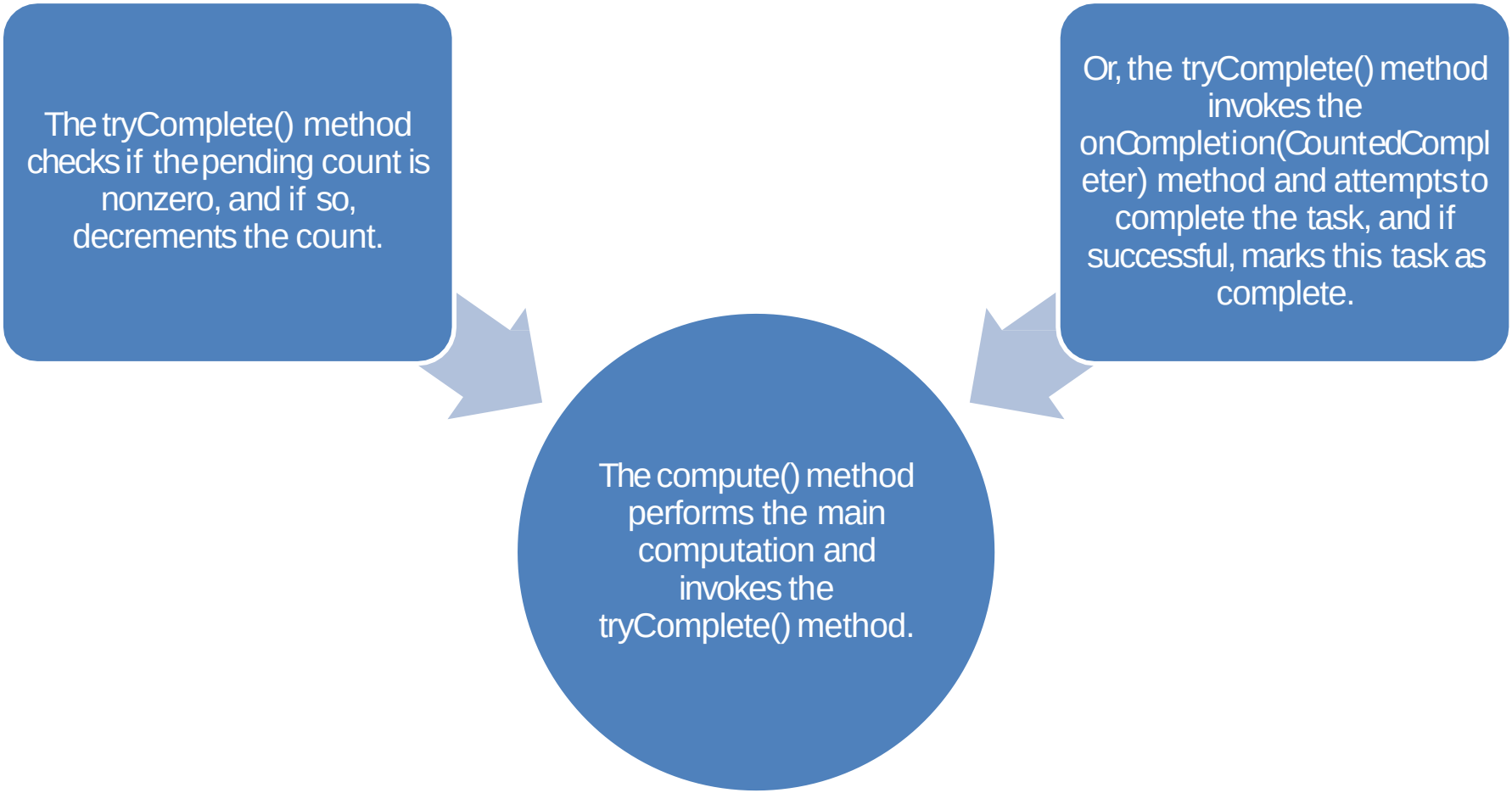
CompletableFuture Class [2-2]

Methods of the **`CompletableFuture`** Class

Method	Description
supplyAsync()	Accepts a Supplier object that contains code to be executed asynchronously
thenApply()	Returns a new CompletableFuture object that is executed with the result of the completed stage, provided the current stage completes normally
join()	Returns the result when the current asynchronous computation completes, or throws an exception of type CompletionException
thenAccept()	Accepts a Consumer object
whenComplete()	Uses BiConsumer as an argument
getNow()	Sets the value passed to it as the result if the calling completion stage is not completed

CountedCompletor Class [1-7]

- The class extends **`ForkJoinTask`** to complete an action performed when triggered, provided there are no pending actions.



CountedCompletor Class [2-7]

- The **`CountedCompletor`** class may override the following methods:

Method	Description
onCompletion(CountedCompleter)	To perform some action upon normal completion.
onExceptionalCompletion(Throwable, CountedCompleter)	To perform some action when an exception is thrown.

CountedCompletor Class [3-7]

- The **`CountedCompleter`** class is declared as **`CountedCompleter<Void>`** when the class does not generate results.
- The class returns null as a value.
- The class must be overridden to yield a value.

CountedCompletor Class [4-7]

- The code demonstrates the implementation of the **CountedCompleter** class.

```
package com.training.demo.countedcompletor;
import java.util.ArrayList;
import java.util.concurrent.*;
public class CountedCompletorDemo {
    static class NumberComputator extends  CountedCompleter<Void> {
        final ConcurrentLinkedQueue<String>  concurrentLinkedQueue;
        final int start, end;
        NumberComputator(ConcurrentLinkedQueue<String>  concurrentLinkedQueue, int start,
        int end) {
            this(concurrentLinkedQueue, start, end, null);
        }
        NumberComputator(ConcurrentLinkedQueue<String>  concurrentLinkedQueue, int start,
        int end,  NumberComputator parent) {
            super(parent);
            this.concurrentLinkedQueue = concurrentLinkedQueue;
            this.start = start;
            this.end = end;
        }
```

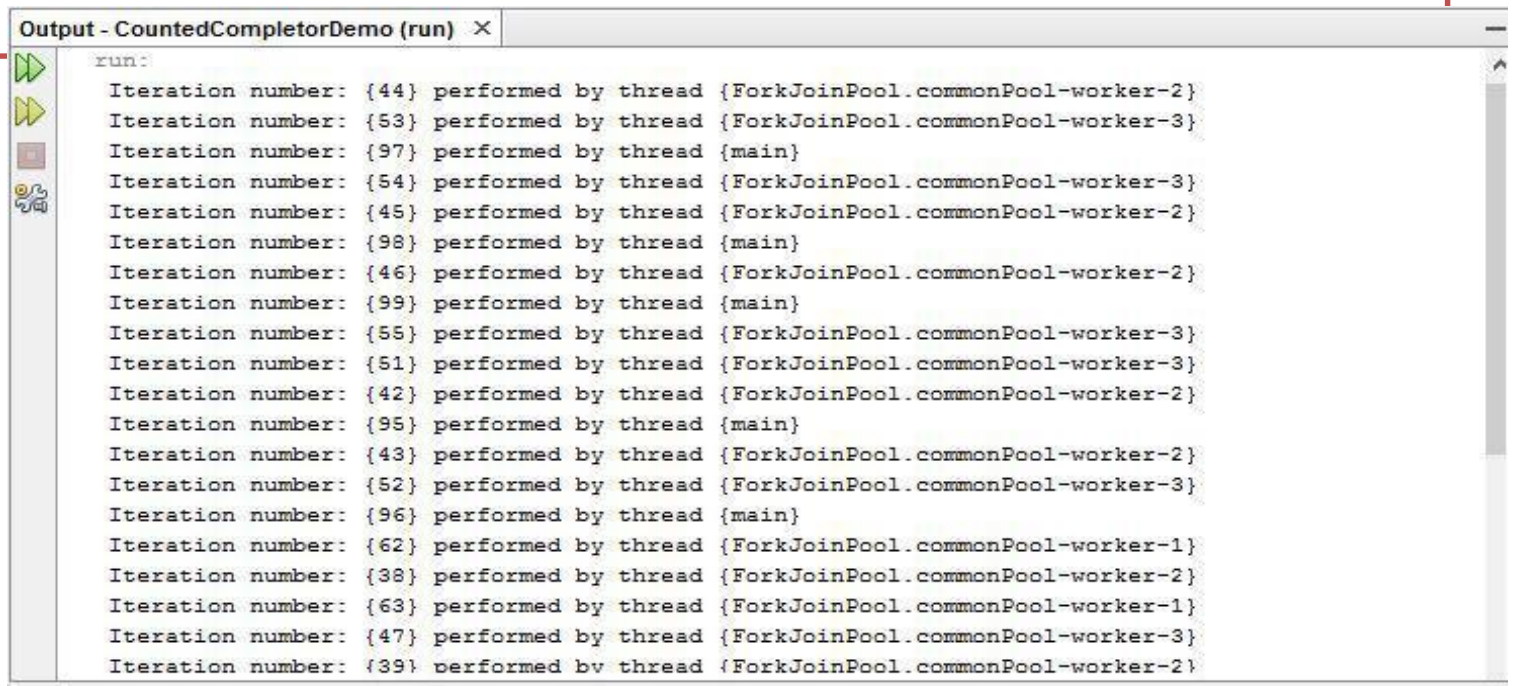
CountedCompletor Class [5-7]

```
    @Override
    public void compute() {
        if (end - start < 5) {
            String s = Thread.currentThread().getName();
            for (int i = start; i < end; i++)
                concurrentLinkedQueue.add(String.format("Iteration  number: {%d} performed by thread
                {%s}", i, s));

            propagateCompletion();
        } else {
            int mid = (end + start) / 2;
            NumberComputator subTaskA = new NumberComputator(concurrentLinkedQueue, start,
            mid, this);
            NumberComputator subTaskB = new  NumberComputator(concurrentLinkedQueue, mid,
            end,  this);
            setPendingCount(1);  subTaskA.fork();  subTaskB.compute();
        }
    }
}
public static void main(String[] args) throws  ExecutionException, InterruptedException {
      ConcurrentLinkedQueue<String> linkedQueue = new ConcurrentLinkedQueue<>();
```

CountedCompletor Class [7-7]

```
        NumberComputator numberComputator = new
        ForkJoinPool.commonPool().invoke(numberComputator);
        ArrayList<String> list = new  ArrayList<>(linkedQueue);
        for (String listItem : list) {
                System.out.println(" " + listItem);
        }
    }
}
```

Following is the output of the code:



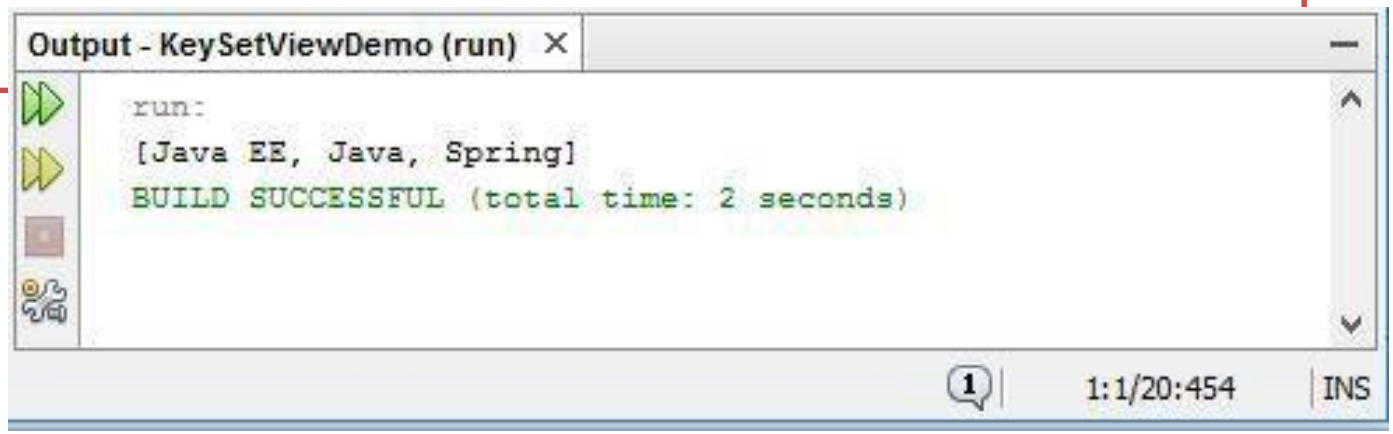
ConcurrentHashMap.KeySetView Class [1-2]

- Provides a view of the keys contained in the class
- Implements the **`Set`** interface and thus, can access the keys as a Set object
- The **`Set`** object and the **`ConcurrentHashMap`** object have a bi-directional relationship

ConcurrentHashMap.KeySetView Class [2-2]

The code demonstrates the method to access the keys of a **ConcurrentHashMap** as a Set.

```
package com.training.demo.keysetview;
import java.util.*;
import java.util.concurrent.ConcurrentHashMap;
public class KeySetViewDemo {
    public static void main(String[] args) {
        Map<String,String> map = new ConcurrentHashMap<>();
        map.put("Spring", "Spring");
        Set keySet = map.keySet();
        System.out.println(keySet);
    }
}
```



Atomic Operations and Locks [1-15]

New classes in the `java.util.concurrent.atomic` package

- `LongAccumulator`: Maintains a long running value updated using a supplied function
- `LongAdder`: Maintains an initially zero long sum
- `DoubleAccumulator`: Maintains a double running value updated using a supplied function
- `DoubleAdder`: Maintains an initially zero double sum

Atomic Operations and Locks [2-15]

- The code demonstrates the use of LongAdder and DoubleAdder atomic operation classes.

```
import java.util.concurrent.atomic.*;
public class AtomicOperationClassDemo {
   private final LongAdder longAdder;
   private final DoubleAdder doubleAdder;

   public AtomicOperationClassDemo(LongAdder longAdder, DoubleAdder doubleAdder) {
      this.longAdder = longAdder;
      this.doubleAdder = doubleAdder;
   }
   public void incrementLong() {
       longAdder.increment();
   }
   public long getLongCounter() {
       return longAdder.longValue();
   }
   public void addDouble(int doubleValue) {
       doubleAdder.add(doubleValue);
   }
   public double getSumAsDouble() {
      return doubleAdder.doubleValue();
   }
```

Atomic Operations and Locks [3-15]

```
public static void main(String[] args) {
      AtomicOperationClassDemo obj = new AtomicOperationClassDemo(new LongAdder(),
      new DoubleAdder());
      System.out.println("-----Long Counter-----");
      for (int i = 0; i < 10; i++) {
         obj.incrementLong();
         System.out.println("Long Counter      " + obj.getLongCounter());
      }
      System.out.println("-----Double Sum-----");
      for (int j = 0; j < 10; j++) {
         obj.addDouble(j);
         System.out.println("Double Sum " + obj.getSumAsDouble());
      }
   }
}
```

```
run:
-----Long Counter-----
Long Counter    1
Long Counter    2
Long Counter    3
Long Counter    4
Long Counter    5
Long Counter    6
Long Counter    7
Long Counter    8
Long Counter    9
Long Counter    10
-----Double Sum-----
Double Sum 0.0
Double Sum 1.0
Double Sum 3.0
Double Sum 6.0
Double Sum 10.0
Double Sum 15.0
Double Sum 21.0
Double Sum 28.0
Double Sum 36.0
Double Sum 45.0
BUILD SUCCESSFUL (total
```

Atomic Operations and Locks [6-15]

- The **`StampedLock`** class of the **`java.util.concurrent.locks`** package enables to implement locks.
- The class returns a long number, also known as stamp, when a lock is granted.
- The stamp is used either to release a lock or to check if the lock is valid.
- The lock supports a new lock mode known as optimistic locking.

Atomic Operations and Locks [7-15]

Implements lock with three modes for read/write access

Writing

- This mode is achieved through the **`writeLock()`** method.
- The **`writeLock()`** method returns a stamp to release a lock.
- This mode is supported by timed and untimed versions of **`tryWriteLock()`** method.
- When a thread is locked in write mode then no read locks can be obtained.

Atomic Operations and Locks [8-15]

Implements lock with three modes for read/write access

Reading

- This mode is achieved through the **`readLock()`** method.
- The **`readLock()`** method returns a stamp to release a lock.
- This mode is supported by timed and untimed versions of **`tryReadLock()`** method.

Atomic Operations and Locks [9-15]

Implements lock with three modes for read/write access

Optimistic Reading

- This mode is achieved through the **`tryOptimisticRead()`** and validate(long) methods.
- The **`tryOptimisticRead()`** returns a non-zero stamp only if the lock in not held in the write mode.
- The **`validate(long)`** returns the value true if the lock has not been acquired by any other thread in the write mode.

Atomic Operations and Locks [10-15]

- Code demonstrates use of the **`StampedLock`** class in reading, writing, and optimistic reading mode.

```
import java.util.concurrent.locks.StampedLock;
public class StampedLockDemo {
    private final StampedLock stampedLock = new StampedLock();
    private double balance;
    public StampedLockDemo(double balance) {
        this.balance = balance;
        System.out.println("Available balance: " + balance);
    }
    public void deposit(double amount) {
        System.out.println("\nAbout to deposit $:  " + amount);
        long stamp = stampedLock.writeLock();
        System.out.println("Applied write lock");
       try {
            balance += amount;
           System.out.println("Available balance: " + balance);
       } finally {
           stampedLock.unlockWrite(stamp);
           System.out.println("Unlocked write lock");
       }
   }
```

Atomic Operations and Locks [11-15]

```
public void withdraw(double amount) {
        System.out.println("\nAbout to withdraw $: " + amount);
        long stamp = stampedLock.writeLock();
        System.out.println("Applied write lock");
        try {
              balance -= amount;
              System.out.println("Available balance: " + balance);
        } finally {
              stampedLock.unlockWrite(stamp);
              System.out.println("Unlocked write lock");
        }
    }
public double checkBalance() {
        System.out.println("\nAbout to check balance");
        long stamp = stampedLock.readLock();
        System.out.println("Applied read lock");
        try {
             System.out.println("Available balance: " + balance);
             return balance;
        } finally {
             stampedLock.unlockRead(stamp);
             System.out.println("Unlocked read lock");
        }
    }
```

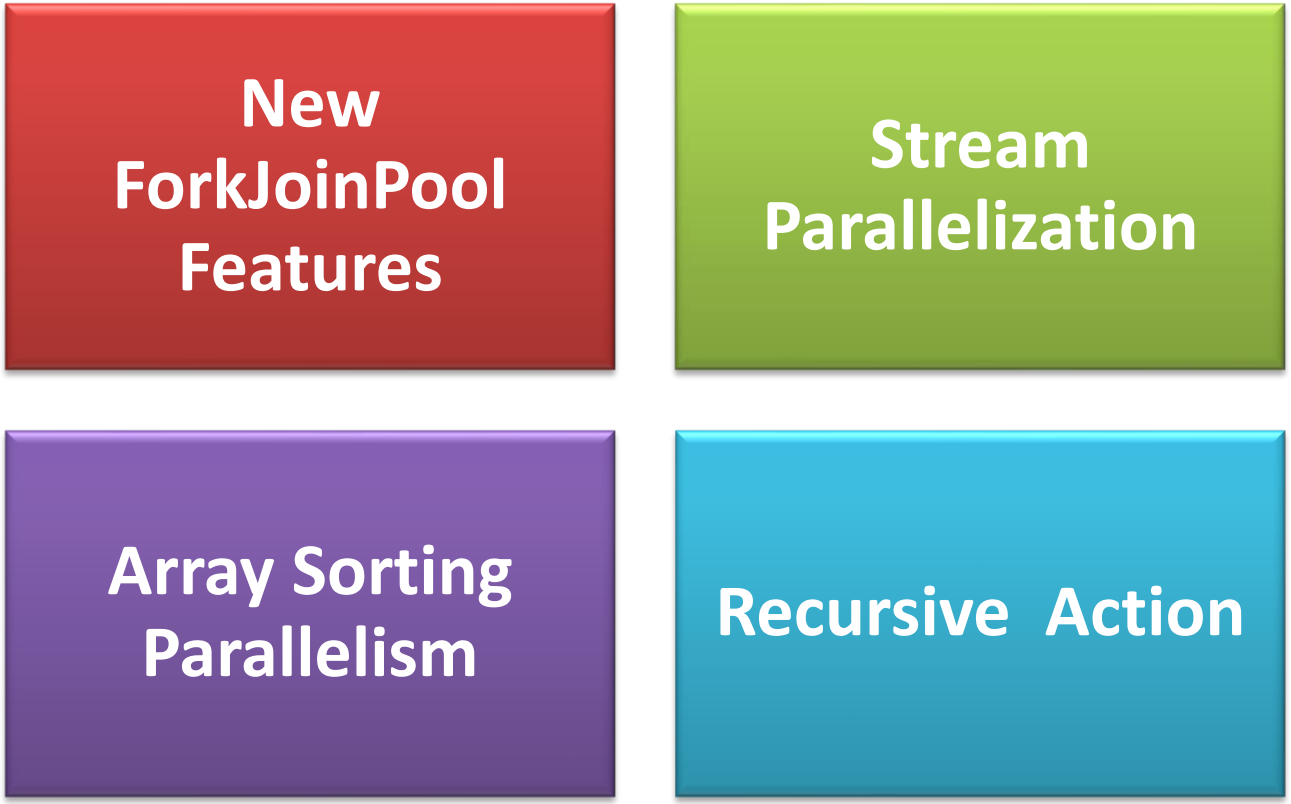
Atomic Operations and Locks [12-15]

```
public double checkBalanceOptimisticRead() {
    System.out.println("\nAbout to check balance with optimistic read lock");
    long stamp = stampedLock.tryOptimisticRead();
    System.out.println("Applied non-blocking optimistic read lock");
    double balance = this.balance;
    if (!stampedLock.validate(stamp)) {
       System.out.println("Stamp have changed. Applying full-blown read lo
       stamp = stampedLock.readLock();
       try {
          balance = this.balance;
       } finally {
          stampedLock.unlockRead(stamp);System.out.println("Unlocked rea
       }
    }
    System.out.println("Available balance: " + balance);
    return balance;
  }

  public static void main(String[] args) {
    StampedLockDemo stampedLockDemo = new StampedLockDemo(4000.00);
    stampedLockDemo.withdraw(1000.00);
    stampedLockDemo.deposit(5000.00);
    stampedLockDemo.checkBalance();
    stampedLockDemo.checkBalanceOptimisticRead();
  }
}
```

```
run:
Available balance: 4000.0

About to withdraw $: 1000.0
Applied write lock
Available balance: 3000.0
Unlocked write lock

About to deposit $:  5000.0
Applied write lock
Available balance: 8000.0
Unlocked write lock

About to check balance
Applied read lock
Available balance: 8000.0
Unlocked read lock

About to check balance with optimisti
Applied non-blocking optimistic read
Available balance: 8000.0
BUILD SUCCESSFUL (total time: 0 secor
```

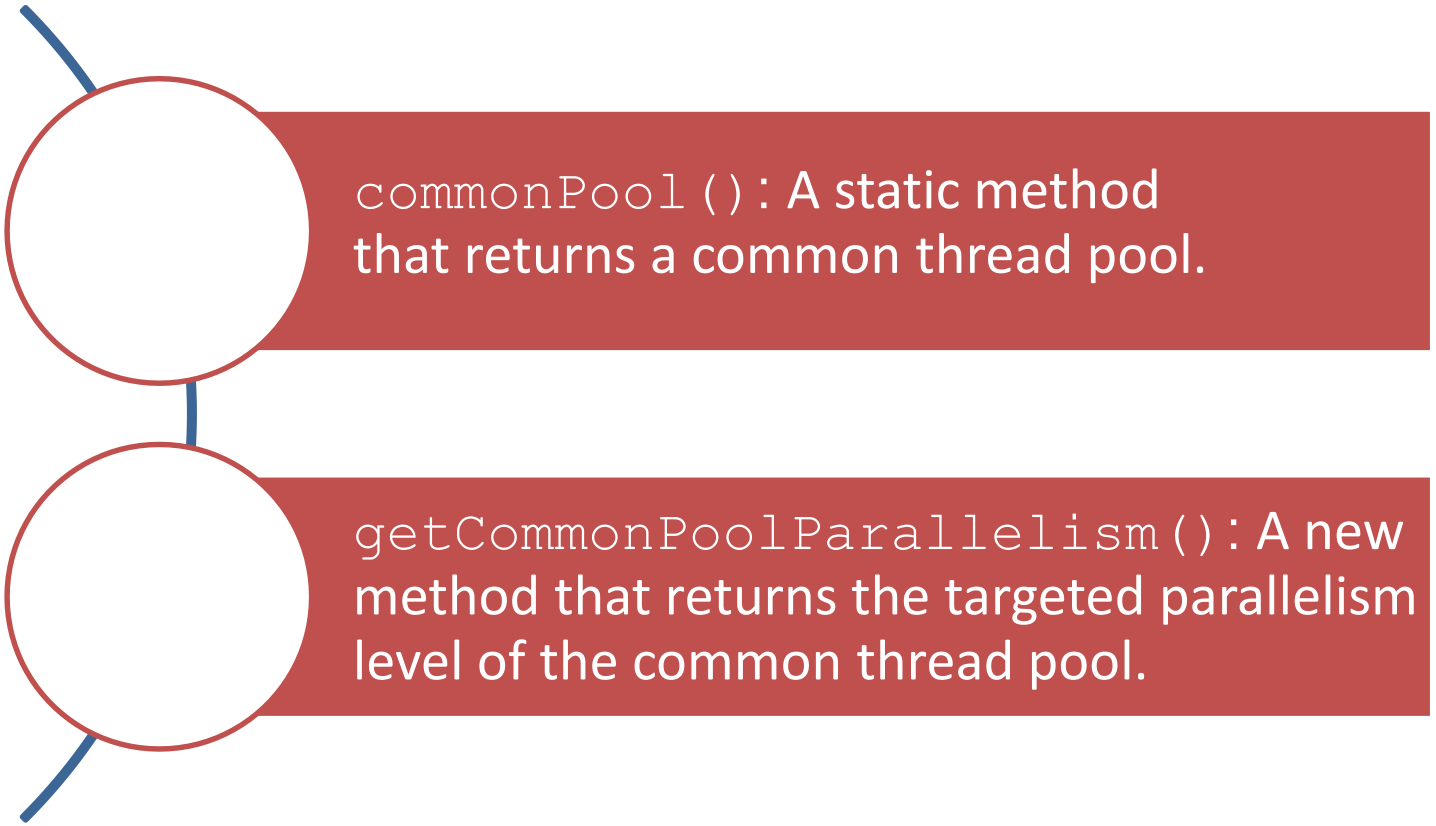
More Features of the Fork-Join Framework

- The framework has included many new features such as:



New ForkJoinPool Features

- Enables the use of a common thread
- Helps the application to reduce resource usage
- Methods included in the **`ForkJoinPool`** class are:

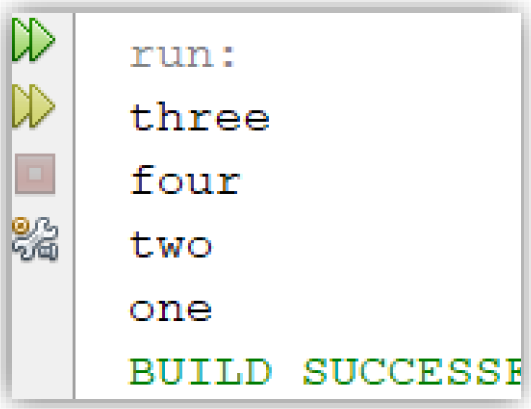


Stream Parallelization

- The code demonstrates the use of parallel stream to iterate through the elements of an ArrayList.

Code Snippet

```
import java.util.*;
import java.util.stream.Stream;

public class ParallelStreamdemo {

   public static void main(String[] args) {
      String [] s = {"one", "two","three", "four"};
      List<String> items = Arrays.asList(s);

      Stream parallelStream = items.parallelStream();
      parallelStream.forEach(System.out::println);

   }
}
```



Arrays Sort Parallelism [1-2]

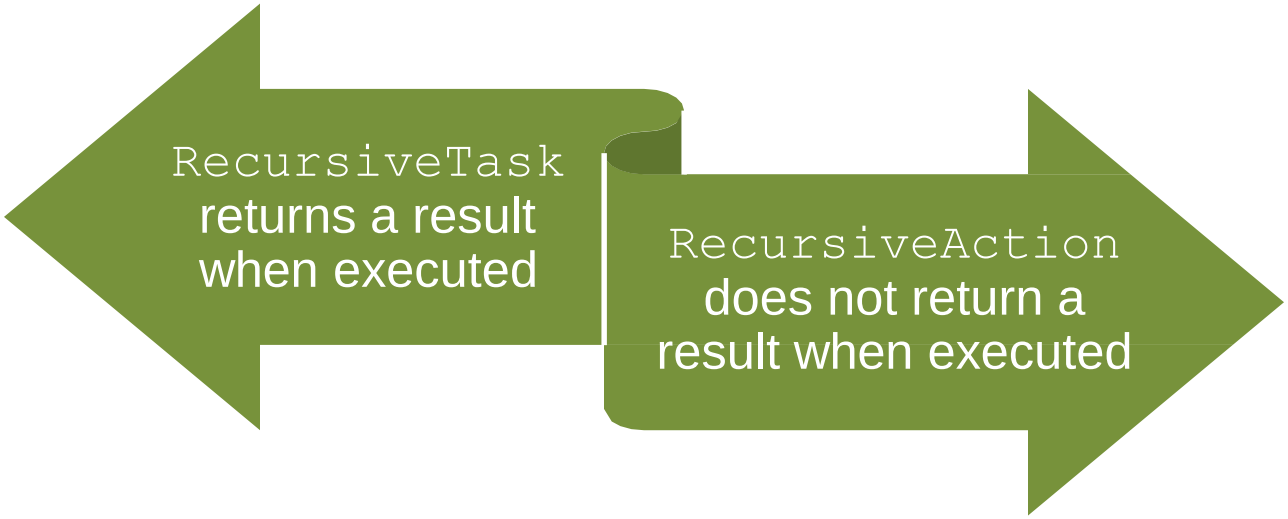
- The code demonstrates how to sort arrays in parallel.

```
import java.util.Arrays;

public class ParallelArraySortDemo {
   public static void main(String[] args) {
      int[] intArray = new int[10];
      for (int i = 0; i < intArray.length; i++) {
         intArray[i] = (int) (Math.random() * 100);
      }
      System.out.println("before sort: ");
      System.out.println(Arrays.toString(intArray));
      Arrays.parallelSort(intArray);
      System.out.println("after sort: ");
      System.out.println(Arrays.toString(intArray));
   }
}
```

```
run:
before sort:
[76, 48, 55, 0, 69, 13, 5, 29, 84, 40]
after sort:
[0, 5, 13, 29, 40, 48, 55, 69, 76, 84]
BUILD SUCCESSFUL (total time: 0 seconds)
```

Recursive Action [1-5]

- The Fork-Join framework extends **`AbstractExecutorService`** class to override the ForkJoinTask processes.
- Two new classes have been to implement the **`ForkJoinTask`** processes:



Recursive Action [2-5]

- The code demonstrates the use of Fork-Join functionality with **`RecursiveAction.`**

```
import java.util.*;
import java.util.concurrent.*;

public class RecursiveActionDemo extends RecursiveAction {

   private long assignedWork = 0;

   public RecursiveActionDemo(long assignedWork) {
      this.assignedWork = assignedWork;
   }

   private List<RecursiveActionDemo> createSubtasks() {
      List<RecursiveActionDemo> subtaskList = new ArrayList<>();
      RecursiveActionDemo subtask1 = new RecursiveActionDemo(this.assignedWork / 2);
      RecursiveActionDemo subtask2 = new RecursiveActionDemo(this.assignedWork / 2);
      subtaskList.add(subtask1);
      subtaskList.add(subtask2);
      return subtaskList;
   }
```

Recursive Action [3-5]

```
protected void compute() {
      if (this.assignedWork > 50) {
         System.out.println("Splitting assignedWork : "
            + Thread.currentThread() + " computing: : " + this.assignedWork);
         List<RecursiveActionDemo> subtaskList = new ArrayList<>();
         subtaskList.addAll(createSubtasks());
         for (RecursiveAction subtask : subtaskList) {
            subtask.fork();
         }
      } else {
         System.out.println("Main thread " + Thread.currentThread() + " computing: : " + this.assignedWork);
      }
   }

   public static void main(String[] args) {
      RecursiveActionDemo recursiveActionDemo = new RecursiveActionDemo(500);
      final ForkJoinPool forkJoinPool = new ForkJoinPool(4);
      forkJoinPool.invoke(recursiveActionDemo);
   }
}
```

```
run:
Splitting assignedWork : Thread[ForkJoinPool-1-worker-1,5,main] computing: : 500
Splitting assignedWork : Thread[ForkJoinPool-1-worker-1,5,main] computing: : 250
Splitting assignedWork : Thread[ForkJoinPool-1-worker-2,5,main] computing: : 250
Splitting assignedWork : Thread[ForkJoinPool-1-worker-1,5,main] computing: : 125
Splitting assignedWork : Thread[ForkJoinPool-1-worker-2,5,main] computing: : 125
Splitting assignedWork : Thread[ForkJoinPool-1-worker-3,5,main] computing: : 125
Splitting assignedWork : Thread[ForkJoinPool-1-worker-3,5,main] computing: : 62
BUILD SUCCESSFUL (total time: 0 seconds)
```

Summary

- The CompletableFuture class simplifies coordination of asynchronous operations.
- The CountedCompletor class represents a completion action performed when triggered, provided there are no remaining pending actions.
- The LongAccumulator, LongAdder, DoubleAccumulator, and DoubleAdder classes provide better throughput improvements as compared to Atomic variables.
- The StampedLock class implements lock to control read/write access.
- Parallel computation of streams enables working with streams faster without the risk of threading issues.
- The new parallelSort() method in the Arrays class allows parallel sorting of array elements.
- RecursiveTask, similar to RecursiveAction extends ForkJoinTask to represent tasks that run within a ForkJoinPool.