Program Structures & Algorithms

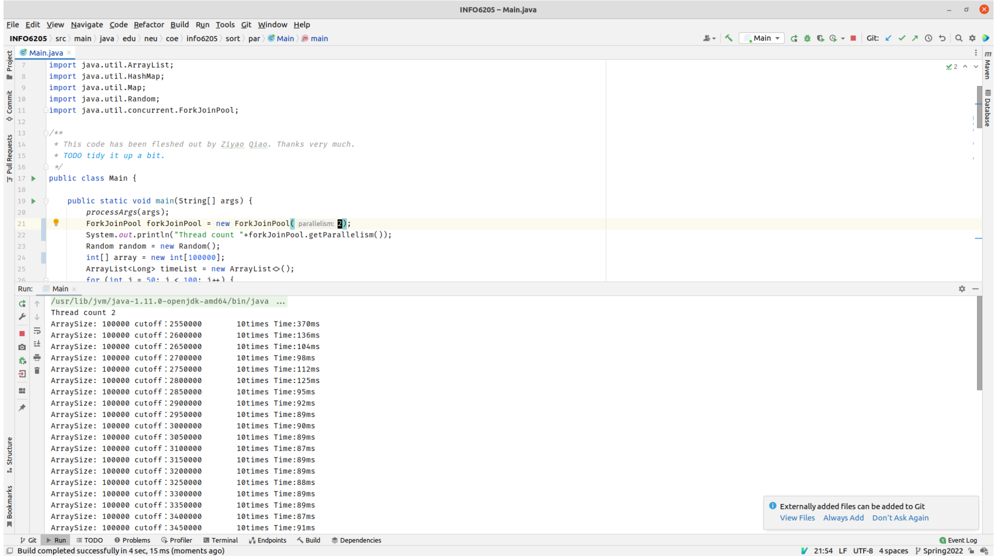
Spring 2022

Assignment No. 4

Name: Surya P

(NUID): 002924467

- **Task:**
    - o Experiment and come up with a good value for the cutoff to switch to parallel. If there are fewer elements to sort than the cutoff, then you should use the system sort instead.
    - o Using the number of available threads, determine an ideal number of separate threads (stick to powers of 2) and arrange for that number of partitions to be parallelized (by preventing recursion after the depth of lg t is reached).
- **Output screenshot**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```java
import java.util.ArrayList;
import java.util.HashMap;
import java.util.Map;
import java.util.Random;
import java.util.concurrent.ForkJoinPool;

/**
 * This code has been fleshed out by Ziyao Qiao. Thanks very much.
 * TODO tidy it up a bit.
 */
public class Main {

    public static void main(String[] args) {
        processArgs(args);
        ForkJoinPool forkJoinPool = new ForkJoinPool( parallelism: 2);
        System.out.println("Thread count "+forkJoinPool.getParallelism());
        Random random = new Random();
        int[] array = new int[100000];
        ArrayList<Long> timeList = new ArrayList<>();
        for (int i = 50; i < 100; i++) {
```

```
/usr/lib/jvm/java-1.11.0-openjdk-amd64/bin/java ...
Thread count 2
ArraySize: 100000 cutoff：2550000       10times Time:370ms
ArraySize: 100000 cutoff：2600000       10times Time:136ms
ArraySize: 100000 cutoff：2650000       10times Time:104ms
ArraySize: 100000 cutoff：2700000       10times Time:98ms
ArraySize: 100000 cutoff：2750000       10times Time:112ms
ArraySize: 100000 cutoff：2800000       10times Time:125ms
ArraySize: 100000 cutoff：2850000       10times Time:95ms
ArraySize: 100000 cutoff：2900000       10times Time:92ms
ArraySize: 100000 cutoff：2950000       10times Time:89ms
ArraySize: 100000 cutoff：3000000       10times Time:90ms
ArraySize: 100000 cutoff：3050000       10times Time:89ms
ArraySize: 100000 cutoff：3100000       10times Time:87ms
ArraySize: 100000 cutoff：3150000       10times Time:89ms
ArraySize: 100000 cutoff：3200000       10times Time:89ms
ArraySize: 100000 cutoff：3250000       10times Time:88ms
ArraySize: 100000 cutoff：3300000       10times Time:89ms
ArraySize: 100000 cutoff：3350000       10times Time:89ms
ArraySize: 100000 cutoff：3400000       10times Time:87ms
ArraySize: 100000 cutoff：3450000       10times Time:91ms
```

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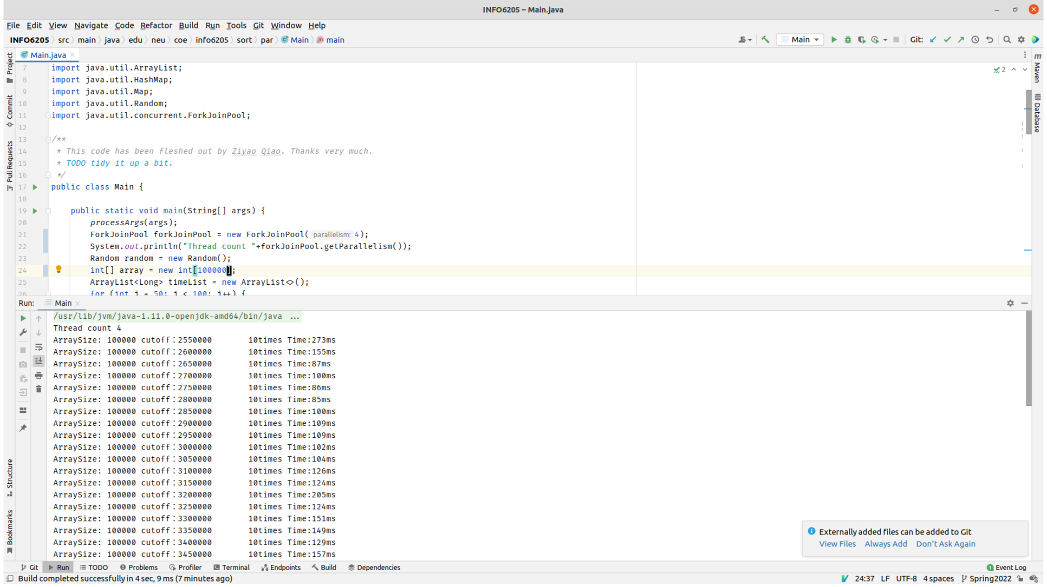
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```
import java.util.ArrayList;
import java.util.HashMap;
import java.util.Map;
import java.util.Random;
import java.util.concurrent.ForkJoinPool;

/**
 * This code has been fleshed out by Ziyao Qiao. Thanks very much.
 * TODO tidy it up a bit.
 */
public class Main {

    public static void main(String[] args) {
        processArgs(args);
        ForkJoinPool forkJoinPool = new ForkJoinPool( parallelism: 4);
        System.out.println("Thread count "+forkJoinPool.getParallelism());
        Random random = new Random();
        int[] array = new int[100000];
        ArrayList<Long> timeList = new ArrayList<>();
        for (int j = 50; j < 100; j++) {
```

```
/usr/lib/jvm/java-1.11.0-openjdk-amd64/bin/java ...
Thread count 4
ArraySize: 100000 cutoff：2550000       10times Time:273ms
ArraySize: 100000 cutoff：2600000       10times Time:155ms
ArraySize: 100000 cutoff：2650000       10times Time:87ms
ArraySize: 100000 cutoff：2700000       10times Time:100ms
ArraySize: 100000 cutoff：2750000       10times Time:86ms
ArraySize: 100000 cutoff：2800000       10times Time:85ms
ArraySize: 100000 cutoff：2850000       10times Time:100ms
ArraySize: 100000 cutoff：2900000       10times Time:109ms
ArraySize: 100000 cutoff：2950000       10times Time:109ms
ArraySize: 100000 cutoff：3000000       10times Time:102ms
ArraySize: 100000 cutoff：3050000       10times Time:104ms
ArraySize: 100000 cutoff：3100000       10times Time:126ms
ArraySize: 100000 cutoff：3150000       10times Time:124ms
ArraySize: 100000 cutoff：3200000       10times Time:205ms
ArraySize: 100000 cutoff：3250000       10times Time:124ms
ArraySize: 100000 cutoff：3300000       10times Time:151ms
ArraySize: 100000 cutoff：3350000       10times Time:149ms
ArraySize: 100000 cutoff：3400000       10times Time:129ms
ArraySize: 100000 cutoff：3450000       10times Time:157ms
```

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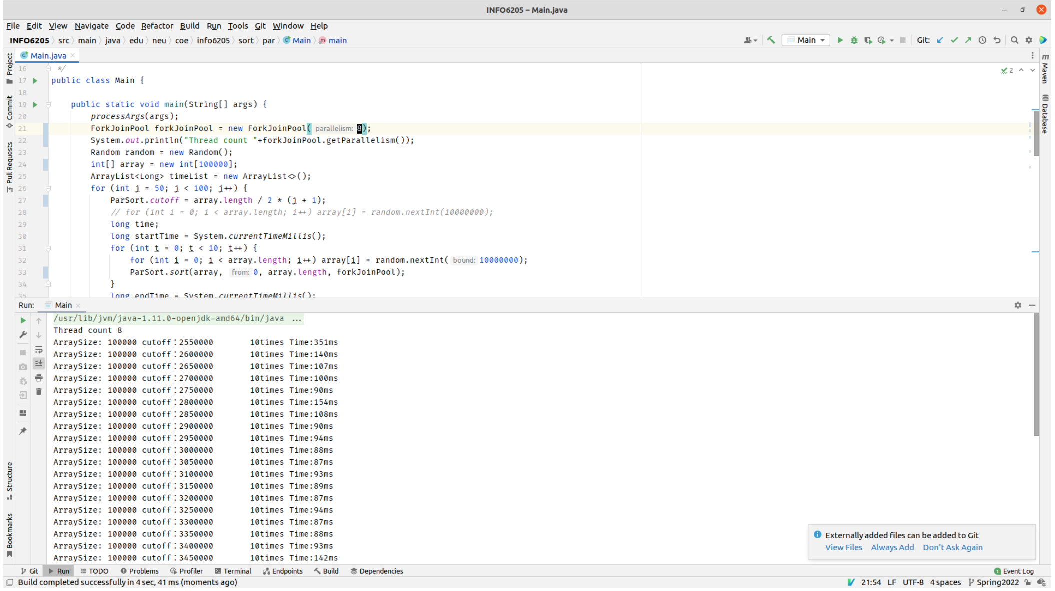
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```
 */
public class Main {

    public static void main(String[] args) {
        processArgs(args);
        ForkJoinPool forkJoinPool = new ForkJoinPool( parallelism: 8);
        System.out.println("Thread count "+forkJoinPool.getParallelism());
        Random random = new Random();
        int[] array = new int[100000];
        ArrayList<Long> timeList = new ArrayList<>();
        for (int j = 50; j < 100; j++) {
            ParSort.cutoff = array.length / 2 * (j + 1);
            // for (int i = 0; i < array.length; i++) array[i] = random.nextInt(10000000);
            long time;
            long startTime = System.currentTimeMillis();
            for (int t = 0; t < 10; t++) {
                for (int i = 0; i < array.length; i++) array[i] = random.nextInt( bound: 10000000);
                ParSort.sort(array,  from: 0, array.length, forkJoinPool);
            }
            long endTime = System.currentTimeMillis();
```

```
/usr/lib/jvm/java-1.11.0-openjdk-amd64/bin/java ...
Thread count 8
ArraySize: 100000 cutoff：2550000       10times Time:351ms
ArraySize: 100000 cutoff：2600000       10times Time:140ms
ArraySize: 100000 cutoff：2650000       10times Time:107ms
ArraySize: 100000 cutoff：2700000       10times Time:100ms
ArraySize: 100000 cutoff：2750000       10times Time:90ms
ArraySize: 100000 cutoff：2800000       10times Time:154ms
ArraySize: 100000 cutoff：2850000       10times Time:108ms
ArraySize: 100000 cutoff：2900000       10times Time:90ms
ArraySize: 100000 cutoff：2950000       10times Time:94ms
ArraySize: 100000 cutoff：3000000       10times Time:88ms
ArraySize: 100000 cutoff：3050000       10times Time:87ms
ArraySize: 100000 cutoff：3100000       10times Time:93ms
ArraySize: 100000 cutoff：3150000       10times Time:89ms
ArraySize: 100000 cutoff：3200000       10times Time:87ms
ArraySize: 100000 cutoff：3250000       10times Time:94ms
ArraySize: 100000 cutoff：3300000       10times Time:87ms
ArraySize: 100000 cutoff：3350000       10times Time:88ms
ArraySize: 100000 cutoff：3400000       10times Time:93ms
ArraySize: 100000 cutoff：3450000       10times Time:142ms
```

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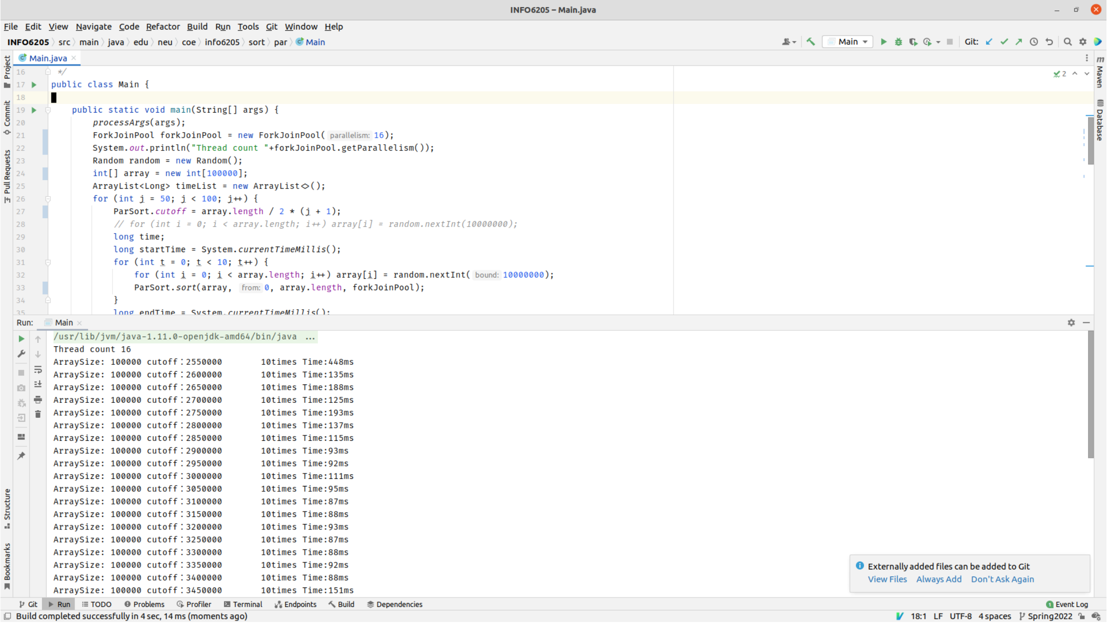
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Main.java
Run: Main
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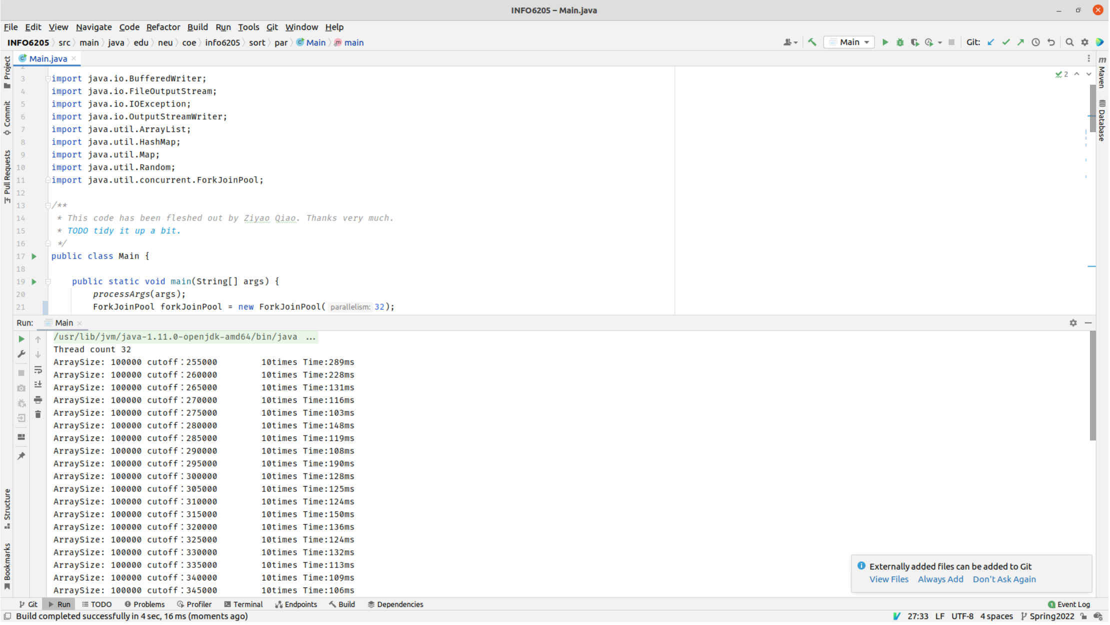
```java
 */
public class Main {

    public static void main(String[] args) {
        processArgs(args);
        ForkJoinPool forkJoinPool = new ForkJoinPool( parallelism: 16);
        System.out.println("Thread count "+forkJoinPool.getParallelism());
        Random random = new Random();
        int[] array = new int[100000];
        ArrayList<Long> timeList = new ArrayList<>();
        for (int j = 50; j < 100; j++) {
            ParSort.cutoff = array.length / 2 * (j + 1);
            // for (int i = 0; i < array.length; i++) array[i] = random.nextInt(10000000);
            long time;
            long startTime = System.currentTimeMillis();
            for (int t = 0; t < 10; t++) {
                for (int i = 0; i < array.length; i++) array[i] = random.nextInt( bound: 10000000);
                ParSort.sort(array,  from: 0, array.length, forkJoinPool);
            }
            long endTime = System.currentTimeMillis();
```

```
/usr/lib/jvm/java-1.11.0-openjdk-amd64/bin/java ...
Thread count 16
ArraySize: 100000 cutoff：2550000       10times Time:448ms
ArraySize: 100000 cutoff：2600000       10times Time:135ms
ArraySize: 100000 cutoff：2650000       10times Time:188ms
ArraySize: 100000 cutoff：2700000       10times Time:125ms
ArraySize: 100000 cutoff：2750000       10times Time:193ms
ArraySize: 100000 cutoff：2800000       10times Time:137ms
ArraySize: 100000 cutoff：2850000       10times Time:115ms
ArraySize: 100000 cutoff：2900000       10times Time:93ms
ArraySize: 100000 cutoff：2950000       10times Time:92ms
ArraySize: 100000 cutoff：3000000       10times Time:111ms
ArraySize: 100000 cutoff：3050000       10times Time:95ms
ArraySize: 100000 cutoff：3100000       10times Time:87ms
ArraySize: 100000 cutoff：3150000       10times Time:88ms
ArraySize: 100000 cutoff：3200000       10times Time:93ms
ArraySize: 100000 cutoff：3250000       10times Time:87ms
ArraySize: 100000 cutoff：3300000       10times Time:88ms
ArraySize: 100000 cutoff：3350000       10times Time:92ms
ArraySize: 100000 cutoff：3400000       10times Time:88ms
ArraySize: 100000 cutoff：3450000       10times Time:151ms
```

Build completed successfully in 4 sec, 14 ms (moments ago)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Main.java
Run: Main
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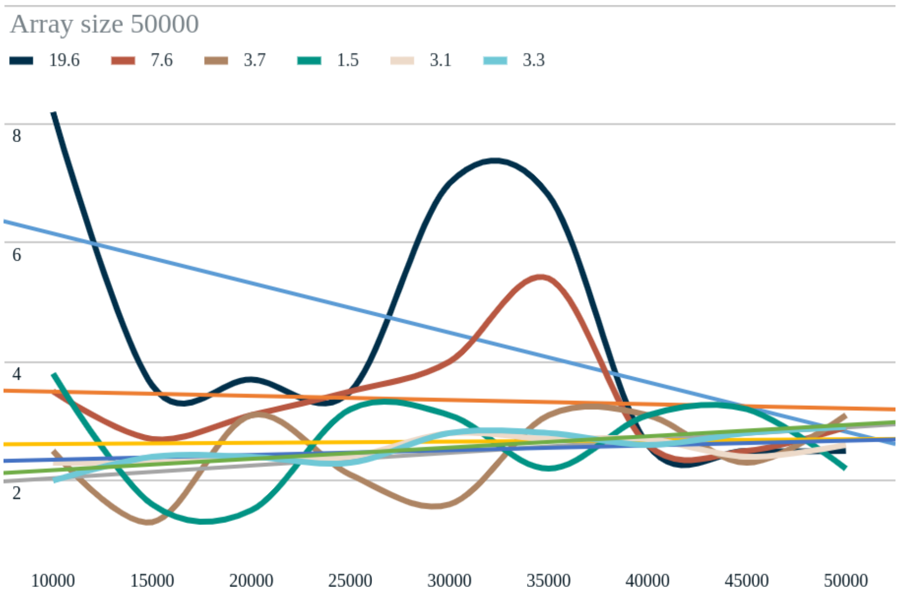
```java
import java.io.BufferedWriter;
import java.io.FileOutputStream;
import java.io.IOException;
import java.io.OutputStreamWriter;
import java.util.ArrayList;
import java.util.HashMap;
import java.util.Map;
import java.util.Random;
import java.util.concurrent.ForkJoinPool;

/**
 * This code has been fleshed out by Ziyao Qiao. Thanks very much.
 * TODO tidy it up a bit.
 */
public class Main {

    public static void main(String[] args) {
        processArgs(args);
        ForkJoinPool forkJoinPool = new ForkJoinPool( parallelism: 32);
```

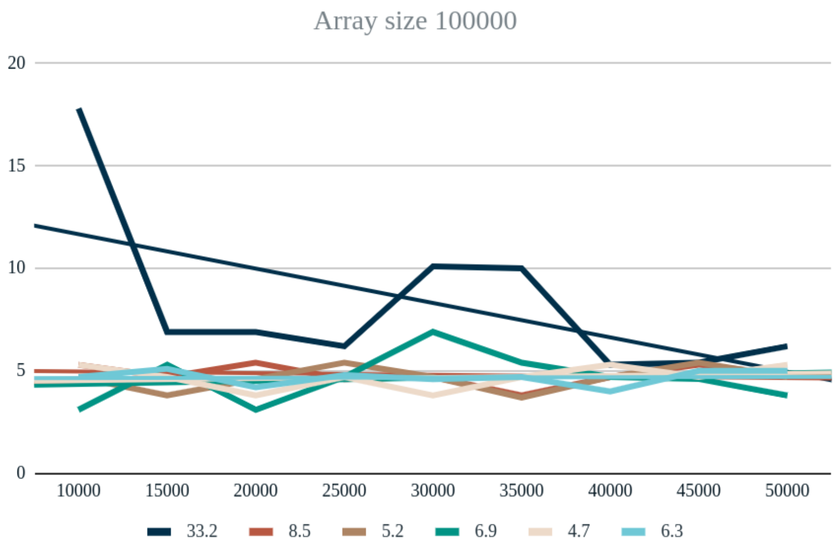
```
/usr/lib/jvm/java-1.11.0-openjdk-amd64/bin/java ...
Thread count 32
ArraySize: 100000 cutoff：255000       10times Time:289ms
ArraySize: 100000 cutoff：260000       10times Time:228ms
ArraySize: 100000 cutoff：265000       10times Time:131ms
ArraySize: 100000 cutoff：270000       10times Time:116ms
ArraySize: 100000 cutoff：275000       10times Time:103ms
ArraySize: 100000 cutoff：280000       10times Time:148ms
ArraySize: 100000 cutoff：285000       10times Time:119ms
ArraySize: 100000 cutoff：290000       10times Time:108ms
ArraySize: 100000 cutoff：295000       10times Time:190ms
ArraySize: 100000 cutoff：300000       10times Time:128ms
ArraySize: 100000 cutoff：305000       10times Time:125ms
ArraySize: 100000 cutoff：310000       10times Time:124ms
ArraySize: 100000 cutoff：315000       10times Time:150ms
ArraySize: 100000 cutoff：320000       10times Time:136ms
ArraySize: 100000 cutoff：325000       10times Time:124ms
ArraySize: 100000 cutoff：330000       10times Time:132ms
ArraySize: 100000 cutoff：335000       10times Time:113ms
ArraySize: 100000 cutoff：340000       10times Time:109ms
ArraySize: 100000 cutoff：345000       10times Time:106ms
```

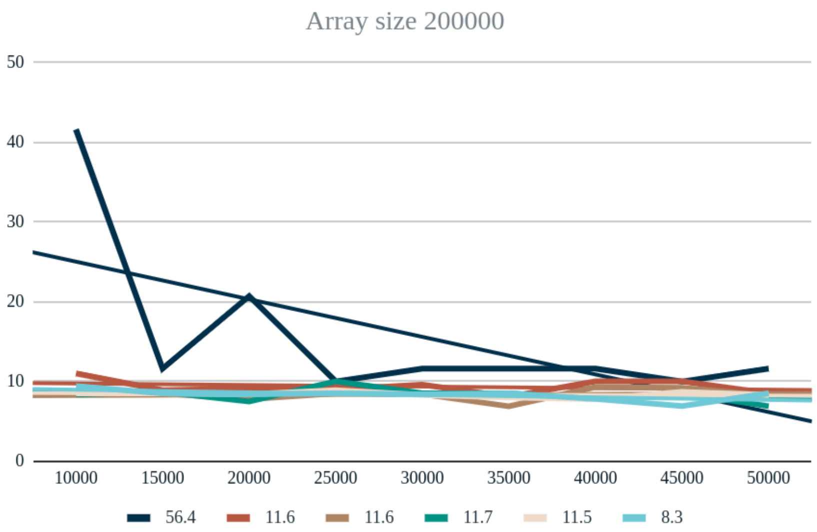
Build completed successfully in 4 sec, 16 ms (moments ago)

- **Relationship Conclusion:**
  - I experimented with using a 4 core machine, on various array sizes and threads counts.
  - From this experiment, it is evident that under 2 threads system sort and parallel sort don't make a huge difference.
  - But anything over 2 threads it is better to use a parallel sort

- **Evidence / Graph:**






Array size 200000
50
40
30
20
10
0
10000
15000
20000
25000
30000
35000
40000
45000
50000
56.4
11.6
11.6
11.7
11.5
8.3