

Program Structures and Algorithms Sec -8

Name: Uday Kiran Reddy Mulpuri **NUID:** 002781063

Assignment-5(Parallel Sorting)

Task:

- Finding Cutoff Length
- Finding Recursion Depth
- Combination of both

Relationship Conclusion:

We have accumulated enough information from simulations of experiments with different combinations of cutoff values, threads, and array sizes to determine a conclusion. Using six threads provides the optimum performance, and using more threads is unlikely to significantly increase performance since the costs associated with creating and synchronizing new threads will begin to outweigh the advantages of parallelism, according to our analysis of the runtimes. In other words, the algorithm's efficiency would not significantly increase if the number of threads were increased above four to five.

Relationship between Recursion Depth(d) and Thread Count(t)

$$d=t/2;$$

$$t=2*d;$$

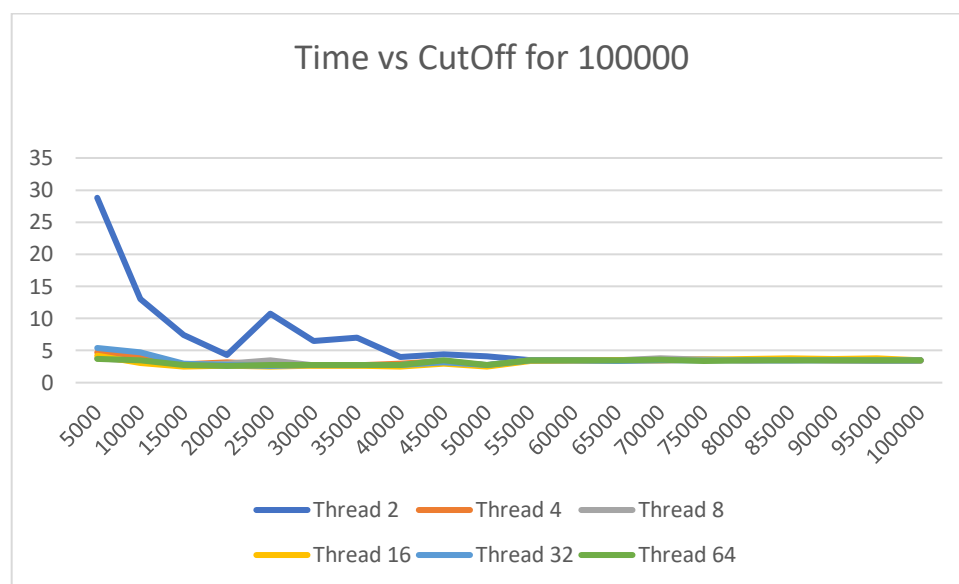
I have Provided more Evidences as runtimes below for different combination of Array Size, Threads and Cutoffs.

Array Size:100000

Thread-2,4,8,16,32,64

Cut Off Length-5%

	Thread 2	Thread 4	Thread 8	Thread 16	Thread 32	Thread 64
5000	28.8	4.7	3.8	4.2	5.4	3.7
10000	13	4.2	3.4	3.1	4.7	3.5
15000	7.4	2.9	2.8	2.5	3	2.7
20000	4.3	3.2	3	2.6	2.8	2.6
25000	10.7	2.9	3.5	2.5	2.6	2.7
30000	6.5	2.7	2.7	2.6	2.8	2.7
35000	7	2.7	2.7	2.6	2.7	2.8
40000	4	3	2.8	2.5	2.7	2.7
45000	4.4	3.4	3.2	3	3.2	3.5
50000	4.1	2.7	2.7	2.5	2.7	2.8
55000	3.5	3.5	3.5	3.4	3.5	3.5
60000	3.5	3.5	3.5	3.5	3.5	3.5
65000	3.5	3.5	3.5	3.5	3.4	3.5
70000	3.6	3.5	3.8	3.5	3.5	3.6
75000	3.6	3.6	3.6	3.6	3.5	3.4
80000	3.5	3.5	3.5	3.7	3.5	3.5
85000	3.5	3.6	3.5	3.8	3.5	3.5
90000	3.6	3.5	3.5	3.7	3.5	3.5
95000	3.5	3.5	3.4	3.8	3.5	3.5
100000	3.5	3.5	3.4	3.5	3.5	3.5



The screenshot displays the Eclipse IDE interface. The Project Explorer on the left shows a project structure with packages like `edu.neu.coe.info6205.dynamicProgramming`, `edu.neu.coe.info6205.graphs`, and `edu.neu.coe.info6205.life`. The Main.java editor shows the following code:

```
1 import java.io.IOException;
2 import java.io.OutputStreamWriter;
3 import java.util.ArrayList;
4
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

The Console window shows the output of the application, which is a performance benchmark. The output is as follows:

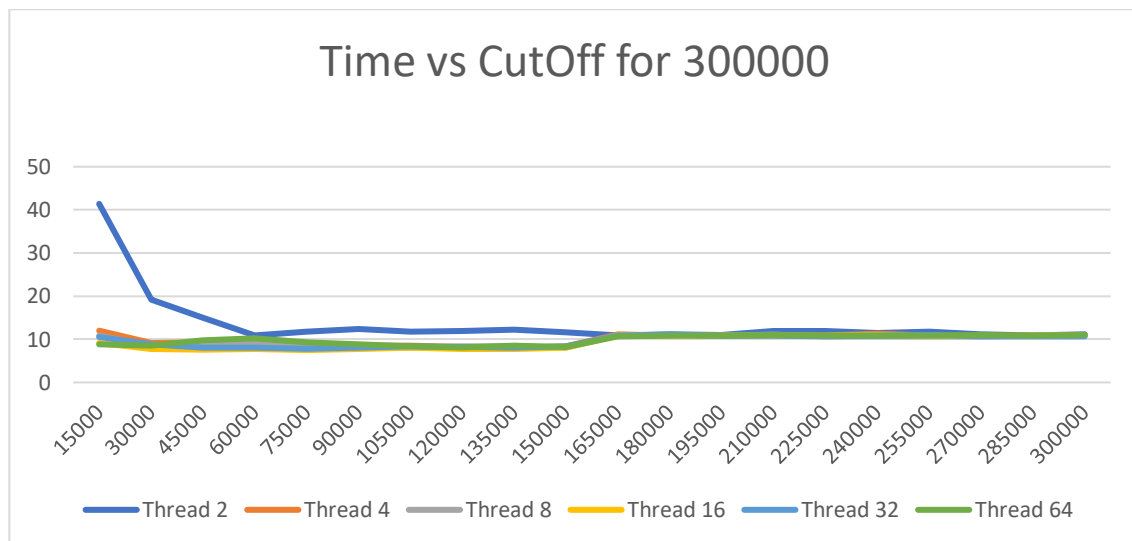
```
<terminated>-Main [Java Application] [Applications\Eclipse.app\Contents\Eclipse\plugins\org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038\jre\bin\java (Feb 18, 2023, 9:35:47 PM - 9:35:47 PM)]
Size of the Array:100000
Degree of parallelism: 2
cutoff: 5000 10times Time:280ms
cutoff: 10000 10times Time:130ms
cutoff: 15000 10times Time:74ms
cutoff: 20000 10times Time:43ms
cutoff: 25000 10times Time:107ms
cutoff: 30000 10times Time:65ms
cutoff: 35000 10times Time:70ms
cutoff: 40000 10times Time:48ms
cutoff: 45000 10times Time:44ms
cutoff: 50000 10times Time:41ms
cutoff: 55000 10times Time:35ms
cutoff: 60000 10times Time:35ms
cutoff: 65000 10times Time:35ms
cutoff: 70000 10times Time:36ms
cutoff: 75000 10times Time:36ms
cutoff: 80000 10times Time:35ms
cutoff: 85000 10times Time:35ms
cutoff: 90000 10times Time:36ms
cutoff: 95000 10times Time:35ms
cutoff: 100000 10times Time:35ms
Degree of parallelism: 4
cutoff: 5000 10times Time:47ms
cutoff: 10000 10times Time:42ms
cutoff: 15000 10times Time:29ms
cutoff: 20000 10times Time:32ms
cutoff: 25000 10times Time:29ms
cutoff: 30000 10times Time:27ms
cutoff: 35000 10times Time:27ms
cutoff: 40000 10times Time:30ms
cutoff: 45000 10times Time:34ms
cutoff: 50000 10times Time:27ms
cutoff: 55000 10times Time:35ms
cutoff: 60000 10times Time:35ms
cutoff: 65000 10times Time:35ms
cutoff: 70000 10times Time:35ms
cutoff: 75000 10times Time:36ms
cutoff: 80000 10times Time:35ms
cutoff: 85000 10times Time:36ms
cutoff: 90000 10times Time:35ms
cutoff: 95000 10times Time:35ms
cutoff: 100000 10times Time:35ms
Degree of parallelism: 16
cutoff: 5000 10times Time:42ms
cutoff: 10000 10times Time:31ms
cutoff: 15000 10times Time:25ms
cutoff: 20000 10times Time:26ms
cutoff: 25000 10times Time:25ms
cutoff: 30000 10times Time:26ms
cutoff: 35000 10times Time:26ms
cutoff: 40000 10times Time:25ms
cutoff: 45000 10times Time:30ms
cutoff: 50000 10times Time:34ms
cutoff: 55000 10times Time:35ms
cutoff: 60000 10times Time:35ms
cutoff: 65000 10times Time:34ms
cutoff: 70000 10times Time:35ms
cutoff: 75000 10times Time:36ms
cutoff: 80000 10times Time:37ms
cutoff: 85000 10times Time:38ms
cutoff: 90000 10times Time:37ms
cutoff: 95000 10times Time:38ms
cutoff: 100000 10times Time:35ms
Degree of parallelism: 32
cutoff: 5000 10times Time:54ms
cutoff: 10000 10times Time:47ms
cutoff: 15000 10times Time:30ms
cutoff: 20000 10times Time:28ms
cutoff: 25000 10times Time:26ms
cutoff: 30000 10times Time:28ms
cutoff: 35000 10times Time:27ms
cutoff: 40000 10times Time:27ms
cutoff: 45000 10times Time:32ms
cutoff: 50000 10times Time:27ms
cutoff: 55000 10times Time:35ms
cutoff: 60000 10times Time:35ms
cutoff: 65000 10times Time:34ms
cutoff: 70000 10times Time:35ms
cutoff: 75000 10times Time:35ms
cutoff: 80000 10times Time:35ms
cutoff: 85000 10times Time:35ms
cutoff: 90000 10times Time:35ms
cutoff: 95000 10times Time:35ms
cutoff: 100000 10times Time:35ms
```

Array Size:300000

Thread-2,4,8,16,32,64

Cut Off Length-5%

	Thread 2	Thread 4	Thread 8	Thread 16	Thread 32	Thread 64
15000	41.4	12	10.8	9.2	10.5	8.8
30000	19.2	9.1	8.3	7.8	8.9	8.6
45000	15	9.3	8.7	7.6	8	9.7
60000	10.9	9.3	9.2	7.8	8	10.2
75000	11.7	8.7	8.5	7.5	7.8	9.3
90000	12.4	8.5	8.1	7.8	8	8.9
105000	11.7	8.6	8.1	8	8.4	8.4
120000	12	8.2	8.3	7.7	8.2	8.1
135000	12.2	8	8.3	7.8	8.1	8.5
150000	11.6	8.3	8.1	8	8.3	8.2
165000	10.9	11.2	11	10.8	10.8	10.7
180000	11.1	10.9	10.8	10.8	11.1	10.8
195000	11	10.9	10.9	10.8	10.8	10.9
210000	11.9	10.9	11.1	10.9	10.9	11
225000	12	10.8	10.7	10.8	10.7	10.8
240000	11.4	11.3	10.7	11	10.8	10.8
255000	11.8	10.9	10.7	10.8	11	10.8
270000	11.1	10.8	10.7	10.7	10.7	11
285000	10.9	10.9	10.9	10.8	10.7	10.9
300000	11.2	11	10.9	10.8	10.7	11



Project Explorer | JUnit

- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.equable
- edu.neu.coe.info6205.functions
- edu.neu.coe.info6205.graphs.BFS_and_prim
- edu.neu.coe.info6205.graphs.dag
- edu.neu.coe.info6205.graphs.Dijkstra
- edu.neu.coe.info6205.graphs.generic_BFS_a
- edu.neu.coe.info6205.graphs.gis
- edu.neu.coe.info6205.graphs.tunnels
- edu.neu.coe.info6205.graphs.undirected
- edu.neu.coe.info6205.greedy
- edu.neu.coe.info6205.lab_1
- edu.neu.coe.info6205.life.base
- edu.neu.coe.info6205.life.library
- edu.neu.coe.info6205.pq
- edu.neu.coe.info6205.randomwalk
- edu.neu.coe.info6205.reduction
- edu.neu.coe.info6205.runLengthEncoding
- > edu.neu.coe.info6205.sort
- edu.neu.coe.info6205.sort.classic
- edu.neu.coe.info6205.sort.counting
- edu.neu.coe.info6205.sort.elementary
- edu.neu.coe.info6205.sort.hashCode
- edu.neu.coe.info6205.sort.linearithmic
- > edu.neu.coe.info6205.sort.par
- edu.neu.coe.info6205.symbolTable
- edu.neu.coe.info6205.symbolTable.hashtabl
- edu.neu.coe.info6205.symbolTable.tree
- edu.neu.coe.info6205.threesum
- edu.neu.coe.info6205.union_find
- edu.neu.coe.info6205.util
- src/main/resources
- src/test/java
- src/test/resources
- JRE System Library [JavaSE-11]
- Maven Dependencies
- AssignmentReport
- project
- > src
- > main
- > src
- Assignment5_results
- test
- target
- LICENSE
- pom.xml

Main.java | ParSort.java

```
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

Console X

<terminated> Main [Java Application] | Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 9:55:40 PM - 9:55:40 PM)

Size of the Array: 300000
Degree of parallelism: 2

cutoff: 15000	10times	Time:414ms
cutoff: 30000	10times	Time:192ms
cutoff: 45000	10times	Time:152ms
cutoff: 60000	10times	Time:109ms
cutoff: 75000	10times	Time:117ms
cutoff: 90000	10times	Time:124ms
cutoff: 105000	10times	Time:117ms
cutoff: 120000	10times	Time:120ms
cutoff: 135000	10times	Time:122ms
cutoff: 150000	10times	Time:116ms
cutoff: 165000	10times	Time:109ms
cutoff: 180000	10times	Time:111ms
cutoff: 195000	10times	Time:110ms
cutoff: 210000	10times	Time:119ms
cutoff: 225000	10times	Time:120ms
cutoff: 240000	10times	Time:114ms
cutoff: 255000	10times	Time:118ms
cutoff: 270000	10times	Time:111ms
cutoff: 285000	10times	Time:109ms
cutoff: 300000	10times	Time:112ms

Degree of parallelism: 4

cutoff: 15000	10times	Time:120ms
cutoff: 30000	10times	Time:91ms
cutoff: 45000	10times	Time:93ms
cutoff: 60000	10times	Time:93ms
cutoff: 75000	10times	Time:87ms
cutoff: 90000	10times	Time:85ms
cutoff: 105000	10times	Time:86ms
cutoff: 120000	10times	Time:82ms
cutoff: 135000	10times	Time:80ms
cutoff: 150000	10times	Time:83ms
cutoff: 165000	10times	Time:112ms
cutoff: 180000	10times	Time:109ms
cutoff: 195000	10times	Time:102ms
cutoff: 210000	10times	Time:109ms
cutoff: 225000	10times	Time:108ms
cutoff: 240000	10times	Time:113ms
cutoff: 255000	10times	Time:109ms
cutoff: 270000	10times	Time:108ms
cutoff: 285000	10times	Time:109ms

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Project Explorer | JUnit

- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.equable
- edu.neu.coe.info6205.functions
- edu.neu.coe.info6205.graphs.BFS_and_prim
- edu.neu.coe.info6205.graphs.dag
- edu.neu.coe.info6205.graphs.Dijkstra
- edu.neu.coe.info6205.graphs.generic_BFS_a
- edu.neu.coe.info6205.graphs.gis
- edu.neu.coe.info6205.graphs.tunnels
- edu.neu.coe.info6205.graphs.undirected
- edu.neu.coe.info6205.greedy
- edu.neu.coe.info6205.lab_1
- edu.neu.coe.info6205.life.base
- edu.neu.coe.info6205.life.library
- edu.neu.coe.info6205.pq
- edu.neu.coe.info6205.randomwalk
- edu.neu.coe.info6205.reduction
- edu.neu.coe.info6205.runLengthEncoding
- > edu.neu.coe.info6205.sort
- edu.neu.coe.info6205.sort.classic
- edu.neu.coe.info6205.sort.counting
- edu.neu.coe.info6205.sort.elementary
- edu.neu.coe.info6205.sort.hashCode
- edu.neu.coe.info6205.sort.linearithmic
- > edu.neu.coe.info6205.sort.par
- edu.neu.coe.info6205.symbolTable
- edu.neu.coe.info6205.symbolTable.hashtabl
- edu.neu.coe.info6205.symbolTable.tree
- edu.neu.coe.info6205.threesum
- edu.neu.coe.info6205.union_find
- edu.neu.coe.info6205.util
- src/main/resources
- src/test/java
- src/test/resources
- JRE System Library [JavaSE-11]
- Maven Dependencies
- AssignmentReport
- project
- > src
- > main
- > src
- Assignment5_results
- test
- target
- LICENSE
- pom.xml

Main.java | ParSort.java

```
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

Console X

<terminated> Main [Java Application] | Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 9:55:40 PM - 9:55:40 PM)

Size of the Array: 300000
Degree of parallelism: 32

cutoff: 15000	10times	Time:105ms
cutoff: 30000	10times	Time:89ms
cutoff: 45000	10times	Time:80ms
cutoff: 60000	10times	Time:80ms
cutoff: 75000	10times	Time:78ms
cutoff: 90000	10times	Time:80ms
cutoff: 105000	10times	Time:84ms
cutoff: 120000	10times	Time:82ms
cutoff: 135000	10times	Time:81ms
cutoff: 150000	10times	Time:83ms
cutoff: 165000	10times	Time:108ms
cutoff: 180000	10times	Time:111ms
cutoff: 195000	10times	Time:108ms
cutoff: 210000	10times	Time:109ms
cutoff: 225000	10times	Time:107ms
cutoff: 240000	10times	Time:108ms
cutoff: 255000	10times	Time:110ms
cutoff: 270000	10times	Time:107ms
cutoff: 285000	10times	Time:107ms
cutoff: 300000	10times	Time:107ms

Degree of parallelism: 64

cutoff: 15000	10times	Time:88ms
cutoff: 30000	10times	Time:86ms
cutoff: 45000	10times	Time:97ms
cutoff: 60000	10times	Time:102ms
cutoff: 75000	10times	Time:93ms
cutoff: 90000	10times	Time:89ms
cutoff: 105000	10times	Time:84ms
cutoff: 120000	10times	Time:81ms
cutoff: 135000	10times	Time:85ms
cutoff: 150000	10times	Time:82ms
cutoff: 165000	10times	Time:107ms
cutoff: 180000	10times	Time:108ms
cutoff: 195000	10times	Time:109ms
cutoff: 210000	10times	Time:110ms
cutoff: 225000	10times	Time:108ms
cutoff: 240000	10times	Time:108ms
cutoff: 255000	10times	Time:108ms
cutoff: 270000	10times	Time:110ms
cutoff: 285000	10times	Time:100ms

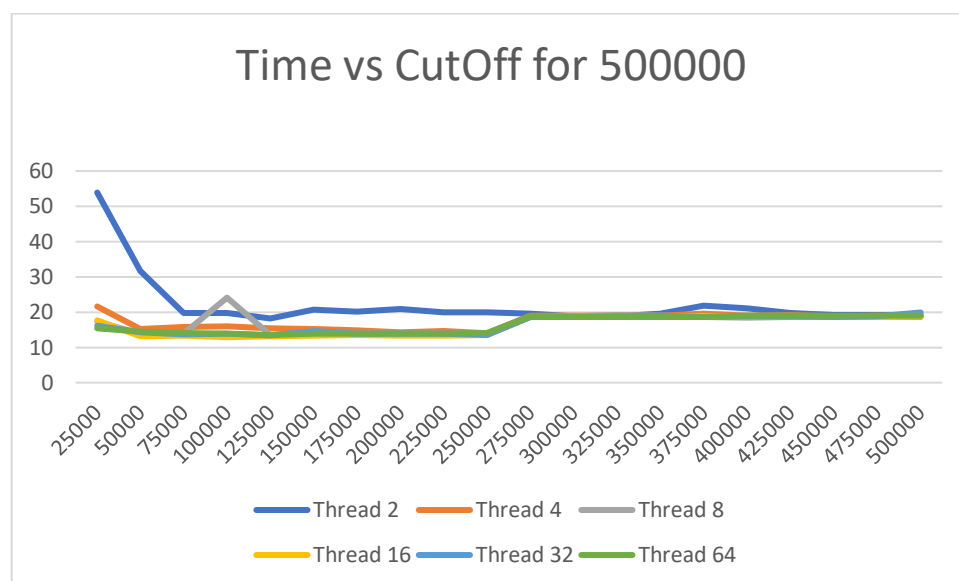
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Array Size:500000

Thread-2,4,8,16,32,64

Cut Off Length-5%

	Thread 2	Thread 4	Thread 8	Thread 16	Thread 32	Thread 64
25000	53.9	21.6	17.3	17.6	16.1	15.4
50000	31.6	15.3	13.9	13.2	14.2	14.4
75000	19.8	15.7	13.8	13.3	13.7	14
100000	19.8	16	24.1	12.9	13.8	13.8
125000	18.2	15.4	13.5	13.2	13.4	13.5
150000	20.7	15.3	13.7	13.4	14.6	13.8
175000	20.1	14.9	13.9	13.6	13.9	13.9
200000	20.9	14.2	13.9	13.4	13.8	13.9
225000	19.9	14.6	13.8	13.4	13.9	13.9
250000	20	14	13.8	13.6	13.6	14.1
275000	19.5	18.9	18.7	18.7	18.6	18.8
300000	18.8	19	18.8	18.6	18.7	18.7
325000	18.8	18.9	19.1	18.6	18.8	18.6
350000	19.6	18.9	18.9	18.7	18.9	18.7
375000	21.9	19.5	18.6	18.9	18.7	18.6
400000	21.1	19	18.5	18.8	18.8	19
425000	19.7	19.1	18.6	18.9	18.8	19
450000	19.2	18.8	18.7	18.7	18.7	18.9
475000	19.1	18.9	18.6	18.7	18.8	19
500000	19.2	18.8	18.7	18.8	19.9	18.9



Project Explorer | JUnit | Main.java | ParSort.java

Console X

terminated- Main [Java Application] [Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 10:04:54 PM - 11

Size of the Array: 500000
Degree of parallelism: 2

cutoff: 25000	10times	Time: 539ms
cutoff: 50000	10times	Time: 316ms
cutoff: 75000	10times	Time: 198ms
cutoff: 100000	10times	Time: 198ms
cutoff: 125000	10times	Time: 182ms
cutoff: 150000	10times	Time: 207ms
cutoff: 175000	10times	Time: 201ms
cutoff: 200000	10times	Time: 209ms
cutoff: 225000	10times	Time: 199ms
cutoff: 250000	10times	Time: 200ms
cutoff: 275000	10times	Time: 195ms
cutoff: 300000	10times	Time: 188ms
cutoff: 325000	10times	Time: 188ms
cutoff: 350000	10times	Time: 196ms
cutoff: 375000	10times	Time: 219ms
cutoff: 400000	10times	Time: 211ms
cutoff: 425000	10times	Time: 197ms
cutoff: 450000	10times	Time: 192ms
cutoff: 475000	10times	Time: 191ms
cutoff: 500000	10times	Time: 192ms

Degree of parallelism: 4

cutoff: 25000	10times	Time: 216ms
cutoff: 50000	10times	Time: 153ms
cutoff: 75000	10times	Time: 157ms
cutoff: 100000	10times	Time: 160ms
cutoff: 125000	10times	Time: 154ms
cutoff: 150000	10times	Time: 153ms
cutoff: 175000	10times	Time: 149ms
cutoff: 200000	10times	Time: 142ms
cutoff: 225000	10times	Time: 146ms
cutoff: 250000	10times	Time: 140ms
cutoff: 275000	10times	Time: 189ms
cutoff: 300000	10times	Time: 190ms
cutoff: 325000	10times	Time: 189ms
cutoff: 350000	10times	Time: 189ms
cutoff: 375000	10times	Time: 195ms
cutoff: 400000	10times	Time: 190ms
cutoff: 425000	10times	Time: 191ms
cutoff: 450000	10times	Time: 188ms
cutoff: 475000	10times	Time: 189ms

Writable Smart Insert 21 : 21 : 511

Project Explorer | JUnit | Main.java | ParSort.java

Console X

terminated- Main [Java Application] [Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 10:04:54 PM - 11

Degree of parallelism: 16

cutoff: 25000	10times	Time: 176ms
cutoff: 50000	10times	Time: 132ms
cutoff: 75000	10times	Time: 133ms
cutoff: 100000	10times	Time: 129ms
cutoff: 125000	10times	Time: 132ms
cutoff: 150000	10times	Time: 134ms
cutoff: 175000	10times	Time: 136ms
cutoff: 200000	10times	Time: 134ms
cutoff: 225000	10times	Time: 134ms
cutoff: 250000	10times	Time: 136ms
cutoff: 275000	10times	Time: 187ms
cutoff: 300000	10times	Time: 186ms
cutoff: 325000	10times	Time: 186ms
cutoff: 350000	10times	Time: 187ms
cutoff: 375000	10times	Time: 189ms
cutoff: 400000	10times	Time: 188ms
cutoff: 425000	10times	Time: 189ms
cutoff: 450000	10times	Time: 187ms
cutoff: 475000	10times	Time: 187ms
cutoff: 500000	10times	Time: 188ms

Degree of parallelism: 32

cutoff: 25000	10times	Time: 161ms
cutoff: 50000	10times	Time: 142ms
cutoff: 75000	10times	Time: 137ms
cutoff: 100000	10times	Time: 138ms
cutoff: 125000	10times	Time: 134ms
cutoff: 150000	10times	Time: 146ms
cutoff: 175000	10times	Time: 139ms
cutoff: 200000	10times	Time: 138ms
cutoff: 225000	10times	Time: 139ms
cutoff: 250000	10times	Time: 136ms
cutoff: 275000	10times	Time: 186ms
cutoff: 300000	10times	Time: 187ms
cutoff: 325000	10times	Time: 188ms
cutoff: 350000	10times	Time: 189ms
cutoff: 375000	10times	Time: 187ms
cutoff: 400000	10times	Time: 188ms
cutoff: 425000	10times	Time: 188ms
cutoff: 450000	10times	Time: 187ms
cutoff: 475000	10times	Time: 188ms
cutoff: 500000	10times	Time: 188ms

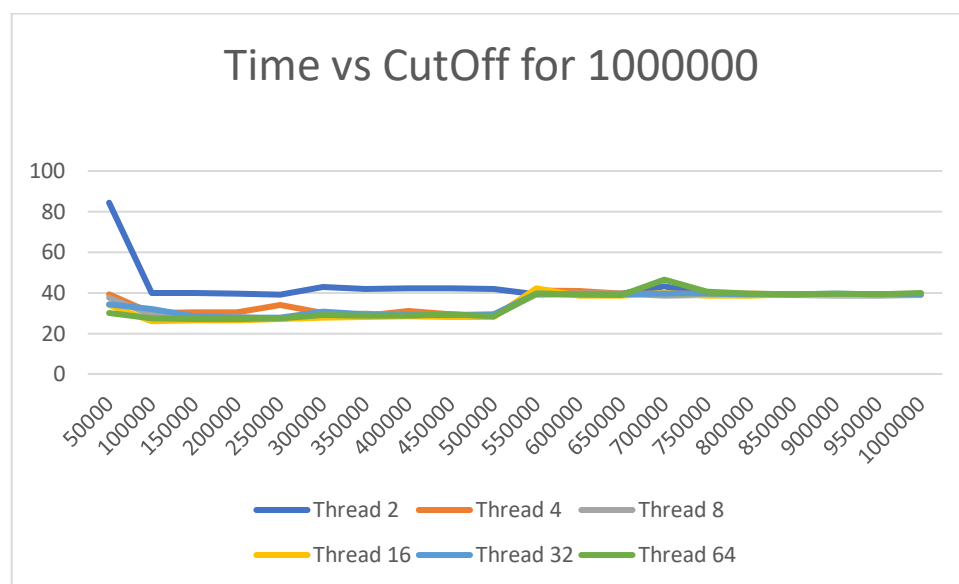
Writable Smart Insert 21 : 21 : 511

Array Size:1000000

Thread-2,4,8,16,32,64

Cut Off Length-5%

	Thread 2	Thread 4	Thread 8	Thread 16	Thread 32	Thread 64
50000	84.4	39.4	37.7	34.1	34.2	30.1
100000	40	30	29.2	26	32.2	27.4
150000	39.8	30.3	26.9	26.6	28.4	27.2
200000	39.5	30.4	28	26.5	27.8	27.1
250000	39.1	34	27.2	27.1	27.9	27.3
300000	43	30	29.1	27.9	30.6	29
350000	42	28.8	29.9	28	29.4	28.8
400000	42.2	31	28.7	28.4	29.2	28.8
450000	42.2	29.4	28.8	28.1	29.2	29.4
500000	42	28.4	28.8	28.2	29.4	28.5
550000	39.3	41.1	39.3	42.2	39.6	39.5
600000	39.3	41	39.7	38.7	39.4	39.4
650000	39.5	39.5	39.5	38.7	39.2	38.8
700000	43.3	39.5	38.6	39.9	39.6	46.5
750000	39.4	39.6	39	38.6	39.5	40.5
800000	39.1	39.5	38.9	38.7	39.3	39.6
850000	39.3	39.3	39	39.4	39.4	39.4
900000	39.3	39.2	38.7	39	39.5	39.7
950000	39.2	39.4	38.7	38.8	39.1	39.4
1000000	39.3	39.2	39	39.3	39.2	39.8



Project Explorer

- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.equable
- edu.neu.coe.info6205.functions
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- edu.neu.coe.info6205.graphs.dag
- edu.neu.coe.info6205.graphs.Dijkstra
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- edu.neu.coe.info6205.graphs.gis
- edu.neu.coe.info6205.graphs.tunnels
- edu.neu.coe.info6205.graphs.undirected
- edu.neu.coe.info6205.greedy
- edu.neu.coe.info6205.lab_1
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- edu.neu.coe.info6205.sort.elementary
- edu.neu.coe.info6205.sort.hashCode
- edu.neu.coe.info6205.sort.linearithmic
- edu.neu.coe.info6205.sort.par
- edu.neu.coe.info6205.symbolTable
- edu.neu.coe.info6205.symbolTable.hashtabl
- edu.neu.coe.info6205.symbolTable.tree
- edu.neu.coe.info6205.threesum
- edu.neu.coe.info6205.union_find
- edu.neu.coe.info6205.util
- src/main/resources
- src/test/java
- src/test/resources
- JRE System Library [JavaSE-11]
- Maven Dependencies
- AssignmentReport
- project
- src
- src
- Assignment5_results
- test
- target
- LICENSE
- pom.xml

Main.java

```
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

Console

```
<terminated> Main [Java Application] Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 10:09:56 PM - 1)
Size of the Array:1000000
Degree of parallelism: 2
cutoff: 50000 10times Time:844ms
cutoff: 100000 10times Time:408ms
cutoff: 150000 10times Time:398ms
cutoff: 200000 10times Time:395ms
cutoff: 250000 10times Time:391ms
cutoff: 300000 10times Time:430ms
cutoff: 350000 10times Time:420ms
cutoff: 400000 10times Time:422ms
cutoff: 450000 10times Time:422ms
cutoff: 500000 10times Time:420ms
cutoff: 550000 10times Time:393ms
cutoff: 600000 10times Time:393ms
cutoff: 650000 10times Time:395ms
cutoff: 700000 10times Time:433ms
cutoff: 750000 10times Time:394ms
cutoff: 800000 10times Time:391ms
cutoff: 850000 10times Time:393ms
cutoff: 900000 10times Time:393ms
cutoff: 950000 10times Time:392ms
cutoff: 1000000 10times Time:393ms
Degree of parallelism: 4
cutoff: 50000 10times Time:394ms
cutoff: 100000 10times Time:300ms
cutoff: 150000 10times Time:303ms
cutoff: 200000 10times Time:304ms
cutoff: 250000 10times Time:340ms
cutoff: 300000 10times Time:300ms
cutoff: 350000 10times Time:288ms
cutoff: 400000 10times Time:310ms
cutoff: 450000 10times Time:294ms
cutoff: 500000 10times Time:284ms
cutoff: 550000 10times Time:411ms
cutoff: 600000 10times Time:410ms
cutoff: 650000 10times Time:395ms
cutoff: 700000 10times Time:395ms
cutoff: 750000 10times Time:396ms
cutoff: 800000 10times Time:395ms
cutoff: 850000 10times Time:393ms
cutoff: 900000 10times Time:392ms
cutoff: 950000 10times Time:394ms
```

Project Explorer

- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.dynamicProgramming
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- edu.neu.coe.info6205.functions
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- edu.neu.coe.info6205.graphs.dag
- edu.neu.coe.info6205.graphs.Dijkstra
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Main.java

```
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

Console

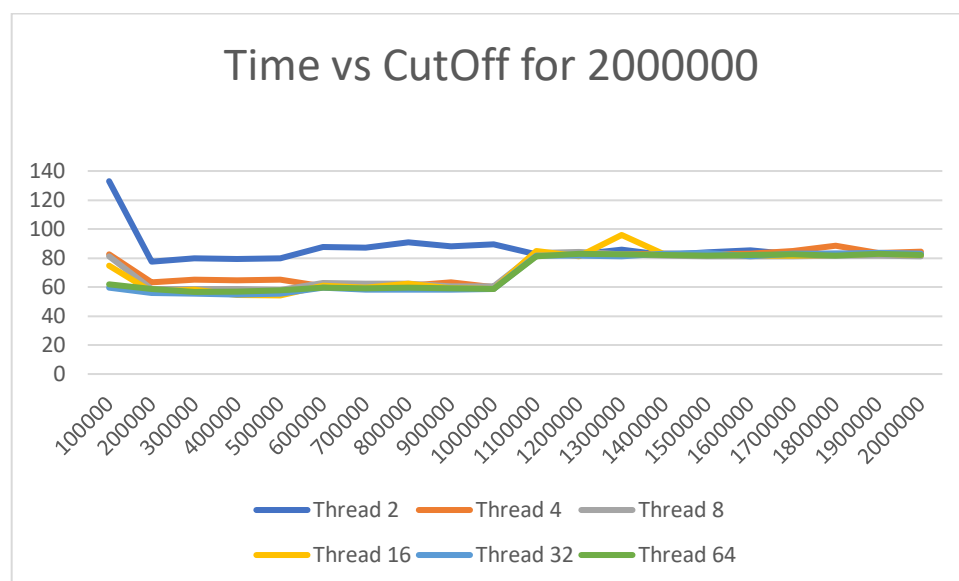
```
<terminated> Main [Java Application] Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 10:09:56 PM - 1)
Degree of parallelism: 32
cutoff: 50000 10times Time:342ms
cutoff: 100000 10times Time:322ms
cutoff: 150000 10times Time:284ms
cutoff: 200000 10times Time:278ms
cutoff: 250000 10times Time:279ms
cutoff: 300000 10times Time:306ms
cutoff: 350000 10times Time:294ms
cutoff: 400000 10times Time:292ms
cutoff: 450000 10times Time:292ms
cutoff: 500000 10times Time:294ms
cutoff: 550000 10times Time:396ms
cutoff: 600000 10times Time:394ms
cutoff: 650000 10times Time:392ms
cutoff: 700000 10times Time:396ms
cutoff: 750000 10times Time:395ms
cutoff: 800000 10times Time:393ms
cutoff: 850000 10times Time:394ms
cutoff: 900000 10times Time:395ms
cutoff: 950000 10times Time:391ms
cutoff: 1000000 10times Time:392ms
Degree of parallelism: 64
cutoff: 50000 10times Time:301ms
cutoff: 100000 10times Time:274ms
cutoff: 150000 10times Time:272ms
cutoff: 200000 10times Time:271ms
cutoff: 250000 10times Time:273ms
cutoff: 300000 10times Time:290ms
cutoff: 350000 10times Time:288ms
cutoff: 400000 10times Time:288ms
cutoff: 450000 10times Time:294ms
cutoff: 500000 10times Time:285ms
cutoff: 550000 10times Time:395ms
cutoff: 600000 10times Time:394ms
cutoff: 650000 10times Time:388ms
cutoff: 700000 10times Time:465ms
cutoff: 750000 10times Time:405ms
cutoff: 800000 10times Time:396ms
cutoff: 850000 10times Time:394ms
cutoff: 900000 10times Time:397ms
cutoff: 950000 10times Time:394ms
```

Array Size:2000000

Thread-2,4,8,16,32,64

Cut Off Length-5%

	Thread 2	Thread 4	Thread 8	Thread 16	Thread 32	Thread 64
100000	133	82.4	81.2	74.9	59.6	61.9
200000	77.5	63.1	58.6	57	55.9	58.6
300000	79.8	64.9	58.7	58.3	55.5	56.6
400000	79.3	64.5	58.5	54.6	54.8	56.8
500000	79.9	65.1	58	54.2	55.3	57.6
600000	87.7	60.5	62.7	61	59.5	59.7
700000	87.3	61.1	62.1	59.6	58.4	59.3
800000	91	60.8	62.3	62.4	58.3	59.6
900000	88.2	63.2	60.5	59	58	59.3
1000000	89.4	59.9	60.6	58.6	58.6	58.6
1100000	82.4	82.9	83.5	84.9	81.6	81.3
1200000	82.7	83.4	84.2	81.2	81.6	82.9
1300000	85.6	82.5	82.5	95.9	81.1	82.4
1400000	82.2	83	81.5	82.7	82.8	82.1
1500000	83.9	82.6	81.4	82.7	83.3	81.7
1600000	85.5	82.8	81	81.6	81.4	82.1
1700000	82.6	84.8	81.4	81.6	82.8	82.5
1800000	82.8	88.5	81.6	82.1	82.8	81.5
1900000	82.5	83.5	81.6	82.9	83.6	82.9
2000000	82.6	84.6	81.2	81.9	83.1	81.9



Project Explorer

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- edu.neu.coe.info6205.graphs.dag
- edu.neu.coe.info6205.graphs.Dijkstra
- edu.neu.coe.info6205.graphs.generic_BFS_a
- edu.neu.coe.info6205.graphs.gis
- edu.neu.coe.info6205.graphs.tunnels
- edu.neu.coe.info6205.graphs.undirected
- edu.neu.coe.info6205.greedy
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- edu.neu.coe.info6205.sort.hashCode
- edu.neu.coe.info6205.sort.linearithmic
- > edu.neu.coe.info6205.sort.par
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- src/main/resources
- src/test/java
- src/test/resources
- JRE System Library [JavaSE-11]
- Maven Dependencies
- AssignmentReport
- project
- > src
- > main
- > src
- Assignment5_results
- test
- target
- LICENSE
- pom.xml

Main.java

```
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

Console

```
<terminated> Main [Java Application] [Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 10:15:58 PM - 10:16:00 PM)]
Size of the Array: 2000000
Degree of parallelism: 2
cutoff: 100000 10times Time:1330ms
cutoff: 200000 10times Time:775ms
cutoff: 300000 10times Time:790ms
cutoff: 400000 10times Time:793ms
cutoff: 500000 10times Time:799ms
cutoff: 600000 10times Time:877ms
cutoff: 700000 10times Time:873ms
cutoff: 800000 10times Time:910ms
cutoff: 900000 10times Time:882ms
cutoff: 1000000 10times Time:894ms
cutoff: 1100000 10times Time:824ms
cutoff: 1200000 10times Time:827ms
cutoff: 1300000 10times Time:856ms
cutoff: 1400000 10times Time:822ms
cutoff: 1500000 10times Time:839ms
cutoff: 1600000 10times Time:855ms
cutoff: 1700000 10times Time:826ms
cutoff: 1800000 10times Time:828ms
cutoff: 1900000 10times Time:825ms
cutoff: 2000000 10times Time:826ms
Degree of parallelism: 4
cutoff: 100000 10times Time:824ms
cutoff: 200000 10times Time:631ms
cutoff: 300000 10times Time:649ms
cutoff: 400000 10times Time:645ms
cutoff: 500000 10times Time:651ms
cutoff: 600000 10times Time:605ms
cutoff: 700000 10times Time:611ms
cutoff: 800000 10times Time:608ms
cutoff: 900000 10times Time:632ms
cutoff: 1000000 10times Time:599ms
cutoff: 1100000 10times Time:629ms
cutoff: 1200000 10times Time:634ms
cutoff: 1300000 10times Time:625ms
cutoff: 1400000 10times Time:630ms
cutoff: 1500000 10times Time:626ms
cutoff: 1600000 10times Time:628ms
cutoff: 1700000 10times Time:648ms
cutoff: 1800000 10times Time:685ms
cutoff: 1900000 10times Time:835ms
```

Project Explorer

- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.dynamicProgramming
- edu.neu.coe.info6205.equable
- edu.neu.coe.info6205.functions
- edu.neu.coe.info6205.graphs.BFS_and_prim
- edu.neu.coe.info6205.graphs.dag
- edu.neu.coe.info6205.graphs.Dijkstra
- edu.neu.coe.info6205.graphs.generic_BFS_a
- edu.neu.coe.info6205.graphs.gis
- edu.neu.coe.info6205.graphs.tunnels
- edu.neu.coe.info6205.graphs.undirected
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- edu.neu.coe.info6205.reduction
- edu.neu.coe.info6205.runLengthEncoding
- > edu.neu.coe.info6205.sort
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- edu.neu.coe.info6205.sort.hashCode
- edu.neu.coe.info6205.sort.linearithmic
- > edu.neu.coe.info6205.sort.par
- edu.neu.coe.info6205.symbolTable
- edu.neu.coe.info6205.symbolTable.hashtabl
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- edu.neu.coe.info6205.union_find
- edu.neu.coe.info6205.util
- src/main/resources
- src/test/java
- src/test/resources
- JRE System Library [JavaSE-11]
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- AssignmentReport
- project
- > src
- > main
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- target
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Main.java

```
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

Console

```
<terminated> Main [Java Application] [Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 10:15:58 PM - 10:16:00 PM)]
cutoff: 2000000 10times Time:849ms
Degree of parallelism: 8
cutoff: 100000 10times Time:812ms
cutoff: 200000 10times Time:586ms
cutoff: 300000 10times Time:587ms
cutoff: 400000 10times Time:585ms
cutoff: 500000 10times Time:580ms
cutoff: 600000 10times Time:627ms
cutoff: 700000 10times Time:621ms
cutoff: 800000 10times Time:623ms
cutoff: 900000 10times Time:605ms
cutoff: 1000000 10times Time:606ms
cutoff: 1100000 10times Time:835ms
cutoff: 1200000 10times Time:842ms
cutoff: 1300000 10times Time:825ms
cutoff: 1400000 10times Time:815ms
cutoff: 1500000 10times Time:814ms
cutoff: 1600000 10times Time:810ms
cutoff: 1700000 10times Time:814ms
cutoff: 1800000 10times Time:816ms
cutoff: 1900000 10times Time:816ms
cutoff: 2000000 10times Time:812ms
Degree of parallelism: 16
cutoff: 100000 10times Time:749ms
cutoff: 200000 10times Time:570ms
cutoff: 300000 10times Time:583ms
cutoff: 400000 10times Time:546ms
cutoff: 500000 10times Time:542ms
cutoff: 600000 10times Time:618ms
cutoff: 700000 10times Time:596ms
cutoff: 800000 10times Time:624ms
cutoff: 900000 10times Time:590ms
cutoff: 1000000 10times Time:586ms
cutoff: 1100000 10times Time:849ms
cutoff: 1200000 10times Time:812ms
cutoff: 1300000 10times Time:959ms
cutoff: 1400000 10times Time:827ms
cutoff: 1500000 10times Time:827ms
cutoff: 1600000 10times Time:816ms
cutoff: 1700000 10times Time:816ms
cutoff: 1800000 10times Time:821ms
cutoff: 1900000 10times Time:829ms
```

Project Explorer | JUnit | Main.java | ParSort.java

```
5 import java.io.IOException;
6 import java.io.OutputStreamWriter;
7 import java.util.ArrayList;
```

Console X

terminated> Main [Java Application] [Applications/Eclipse.app/Contents/Eclipse/plugins/org.eclipse.justi.openjdk.hotspot.jre.full.macosx.x86_64_17.0.4.v20220903-1038/jre/bin/java (Feb 18, 2023, 10:15:58 PM - 10:16:00 PM)]

cutoff: 2000000	10times	Time:819ms
Degree of parallelism: 32		
cutoff: 100000	10times	Time:596ms
cutoff: 200000	10times	Time:559ms
cutoff: 300000	10times	Time:555ms
cutoff: 400000	10times	Time:548ms
cutoff: 500000	10times	Time:553ms
cutoff: 600000	10times	Time:595ms
cutoff: 700000	10times	Time:584ms
cutoff: 800000	10times	Time:583ms
cutoff: 900000	10times	Time:580ms
cutoff: 1000000	10times	Time:586ms
cutoff: 1100000	10times	Time:816ms
cutoff: 1200000	10times	Time:816ms
cutoff: 1300000	10times	Time:811ms
cutoff: 1400000	10times	Time:828ms
cutoff: 1500000	10times	Time:833ms
cutoff: 1600000	10times	Time:814ms
cutoff: 1700000	10times	Time:828ms
cutoff: 1800000	10times	Time:828ms
cutoff: 1900000	10times	Time:836ms
cutoff: 2000000	10times	Time:831ms
Degree of parallelism: 64		
cutoff: 100000	10times	Time:619ms
cutoff: 200000	10times	Time:586ms
cutoff: 300000	10times	Time:566ms
cutoff: 400000	10times	Time:568ms
cutoff: 500000	10times	Time:576ms
cutoff: 600000	10times	Time:597ms
cutoff: 700000	10times	Time:593ms
cutoff: 800000	10times	Time:596ms
cutoff: 900000	10times	Time:593ms
cutoff: 1000000	10times	Time:586ms
cutoff: 1100000	10times	Time:813ms
cutoff: 1200000	10times	Time:829ms
cutoff: 1300000	10times	Time:824ms
cutoff: 1400000	10times	Time:821ms
cutoff: 1500000	10times	Time:817ms
cutoff: 1600000	10times	Time:821ms
cutoff: 1700000	10times	Time:825ms
cutoff: 1800000	10times	Time:815ms
cutoff: 1900000	10times	Time:829ms

Project Explorer

- edu.neu.coe.info6205.dynamicProgramming.
- edu.neu.coe.info6205.dynamicProgramming.
- edu.neu.coe.info6205.equable
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