Program Structures and Algorithms

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**Task:**

Your task is to implement a parallel sorting algorithm such that each partition of the array is sorted in parallel. You will consider two different schemes for deciding whether to sort in parallel.

1. A cutoff (defaults to, say, 1000) which you will update according to the first argument in the command line when running. It's your job to experiment and come up with a good value for this cutoff. If there are fewer elements to sort than the cutoff, then you should use the system sort instead.
2. Recursion depth or the number of available threads. Using this determination, you might decide on an ideal number (*t*) 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).
3. An appropriate combination of these.

**Relationship Conclusion:**

After experimenting with various cutoff values and thread counts for various array sizes, we can

say that four threads is the ideal amount because the algorithm's performance doesn't dramatically improve after that.

The lowest performance is achieved when the cutoff value is 25% of the array size.

**Evidence to support the conclusion:**

**Array size : 2000000**

|  |  |  |  |
| --- | --- | --- | --- |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 2 | 2000000 | 1763ms |
| 10000 | 2 | 2000000 | 1732ms |
| 15000 | 2 | 2000000 | 1751ms |
| 20000 | 2 | 2000000 | 1700ms |
| 25000 | 2 | 2000000 | 1752ms |
| 30000 | 2 | 2000000 | 1775ms |
| 35000 | 2 | 2000000 | 1743ms |
| 40000 | 2 | 2000000 | 1555ms |
| 45000 | 2 | 2000000 | 1674ms |
| 50000 | 2 | 2000000 | 1650ms |
|  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 4 | 2000000 | 1554ms |
| 10000 | 4 | 2000000 | 1455ms |
| 15000 | 4 | 2000000 | 1459ms |
| 20000 | 4 | 2000000 | 1221ms |
| 25000 | 4 | 2000000 | 1276ms |
| 30000 | 4 | 2000000 | 1320ms |
| 35000 | 4 | 2000000 | 1302ms |
| 40000 | 4 | 2000000 | 1333ms |
| 45000 | 4 | 2000000 | 1376ms |
| 50000 | 4 | 2000000 | 1460ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 8 | 2000000 | 1495ms |
| 10000 | 8 | 2000000 | 1479ms |
| 15000 | 8 | 2000000 | 1282ms |
| 20000 | 8 | 2000000 | 1305ms |
| 25000 | 8 | 2000000 | 1073ms |
| 30000 | 8 | 2000000 | 1151ms |
| 35000 | 8 | 2000000 | 1273ms |
| 40000 | 8 | 2000000 | 1113ms |
| 45000 | 8 | 2000000 | 1296ms |
| 50000 | 8 | 2000000 | 1235ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 16 | 2000000 | 1573ms |
| 10000 | 16 | 2000000 | 1358ms |
| 15000 | 16 | 2000000 | 1224ms |
| 20000 | 16 | 2000000 | 1338ms |
| 25000 | 16 | 2000000 | 1313ms |
| 30000 | 16 | 2000000 | 1292ms |
| 35000 | 16 | 2000000 | 901ms |
| 40000 | 16 | 2000000 | 1294ms |
| 45000 | 16 | 2000000 | 1266ms |
| 50000 | 16 | 2000000 | 1303ms |
|  |  |  |  |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 32 | 2000000 | 1602ms |
| 10000 | 32 | 2000000 | 1455ms |
| 15000 | 32 | 2000000 | 1091ms |
| 20000 | 32 | 2000000 | 1210ms |
| 25000 | 32 | 2000000 | 1254ms |
| 30000 | 32 | 2000000 | 1169ms |
| 35000 | 32 | 2000000 | 1308ms |
| 40000 | 32 | 2000000 | 1347ms |
| 45000 | 32 | 2000000 | 1322ms |
| 50000 | 32 | 2000000 | 1219ms |

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**Array size :** 100000

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| --- | --- | --- | --- |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 2 | 100000 | 99ms |
| 10000 | 2 | 100000 | 78ms |
| 15000 | 2 | 100000 | 39ms |
| 20000 | 2 | 100000 | 39ms |
| 25000 | 2 | 100000 | 55ms |
| 30000 | 2 | 100000 | 35ms |
| 35000 | 2 | 100000 | 41ms |
| 40000 | 2 | 100000 | 33ms |
| 45000 | 2 | 100000 | 33ms |
| 50000 | 2 | 100000 | 34ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 4 | 100000 | 110ms |
| 10000 | 4 | 100000 | 63ms |
| 15000 | 4 | 100000 | 32ms |
| 20000 | 4 | 100000 | 45ms |
| 25000 | 4 | 100000 | 43ms |
| 30000 | 4 | 100000 | 30ms |
| 35000 | 4 | 100000 | 39ms |
| 40000 | 4 | 100000 | 28ms |
| 45000 | 4 | 100000 | 39ms |
| 50000 | 4 | 100000 | 25ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 8 | 100000 | 98ms |
| 10000 | 8 | 100000 | 87ms |
| 15000 | 8 | 100000 | 33ms |
| 20000 | 8 | 100000 | 47ms |
| 25000 | 8 | 100000 | 30ms |
| 30000 | 8 | 100000 | 30ms |
| 35000 | 8 | 100000 | 31ms |
| 40000 | 8 | 100000 | 28ms |
| 45000 | 8 | 100000 | 32ms |
| 50000 | 8 | 100000 | 46ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 16 | 100000 | 119ms |
| 10000 | 16 | 100000 | 48ms |
| 15000 | 16 | 100000 | 30ms |
| 20000 | 16 | 100000 | 42ms |
| 25000 | 16 | 100000 | 31ms |
| 30000 | 16 | 100000 | 29ms |
| 35000 | 16 | 100000 | 62ms |
| 40000 | 16 | 100000 | 27ms |
| 45000 | 16 | 100000 | 27ms |
| 50000 | 16 | 100000 | 27ms |
|  |  |  |  |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 32 | 100000 | 121ms |
| 10000 | 32 | 100000 | 67ms |
| 15000 | 32 | 100000 | 29ms |
| 20000 | 32 | 100000 | 30ms |
| 25000 | 32 | 100000 | 31ms |
| 30000 | 32 | 100000 | 44ms |
| 35000 | 32 | 100000 | 54ms |
| 40000 | 32 | 100000 | 37ms |
| 45000 | 32 | 100000 | 26ms |
| 50000 | 32 | 100000 | 38ms |

Array size : 50000

|  |  |  |  |
| --- | --- | --- | --- |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 2 | 50000 | 61ms |
| 10000 | 2 | 50000 | 47ms |
| 15000 | 2 | 50000 | 32ms |
| 20000 | 2 | 50000 | 39ms |
| 25000 | 2 | 50000 | 50ms |
| 30000 | 2 | 50000 | 33ms |
| 35000 | 2 | 50000 | 31ms |
| 40000 | 2 | 50000 | 33ms |
| 45000 | 2 | 50000 | 28ms |
| 50000 | 2 | 50000 | 31ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 4 | 50000 | 51ms |
| 10000 | 4 | 50000 | 50ms |
| 15000 | 4 | 50000 | 25ms |
| 20000 | 4 | 50000 | 28ms |
| 25000 | 4 | 50000 | 27ms |
| 30000 | 4 | 50000 | 27ms |
| 35000 | 4 | 50000 | 19ms |
| 40000 | 4 | 50000 | 20ms |
| 45000 | 4 | 50000 | 19ms |
| 50000 | 4 | 50000 | 22ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 8 | 50000 | 93ms |
| 10000 | 8 | 50000 | 76ms |
| 15000 | 8 | 50000 | 42ms |
| 20000 | 8 | 50000 | 30ms |
| 25000 | 8 | 50000 | 31ms |
| 30000 | 8 | 50000 | 45ms |
| 35000 | 8 | 50000 | 43ms |
| 40000 | 8 | 50000 | 29ms |
| 45000 | 8 | 50000 | 25ms |
| 50000 | 8 | 50000 | 31ms |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 16 | 50000 | 66ms |
| 10000 | 16 | 50000 | 25ms |
| 15000 | 16 | 50000 | 25ms |
| 20000 | 16 | 50000 | 29ms |
| 25000 | 16 | 50000 | 25ms |
| 30000 | 16 | 50000 | 20ms |
| 35000 | 16 | 50000 | 25ms |
| 40000 | 16 | 50000 | 21ms |
| 45000 | 16 | 50000 | 19ms |
| 50000 | 16 | 50000 | 17ms |
|  |  |  |  |
|  |  |  |  |
| Cutoff | Degree of parallelism | Array Size | Time of execution |
| 5000 | 32 | 50000 | 87ms |
| 10000 | 32 | 50000 | 44ms |
| 15000 | 32 | 50000 | 18ms |
| 20000 | 32 | 50000 | 16ms |
| 25000 | 32 | 50000 | 18ms |
| 30000 | 32 | 50000 | 35ms |
| 35000 | 32 | 50000 | 37ms |
| 40000 | 32 | 50000 | 17ms |
| 45000 | 32 | 50000 | 16ms |
| 50000 | 32 | 50000 | 17ms |

**Graphical Representation:**

**Array size : 100000 Thread 16**

|  |  |
| --- | --- |
| Cutoff | Time of execution |
| 5000 | 119ms |
| 10000 | 48ms |
| 15000 | 30ms |
| 20000 | 42ms |
| 25000 | 31ms |
| 30000 | 29ms |
| 35000 | 62ms |
| 40000 | 27ms |
| 45000 | 27ms |
| 50000 | 27ms |

**Chart, line chart

Description automatically generated**

**Array size : 50000 Thread 16**

|  |  |
| --- | --- |
| Cutoff | Time of execution |
| 5000 | 66ms |
| 10000 | 25ms |
| 15000 | 25ms |
| 20000 | 29ms |
| 25000 | 25ms |
| 30000 | 20ms |
| 35000 | 25ms |
| 40000 | 21ms |
| 45000 | 19ms |
| 50000 | 17ms |

**Chart, line chart

Description automatically generated**

**Console Output:**

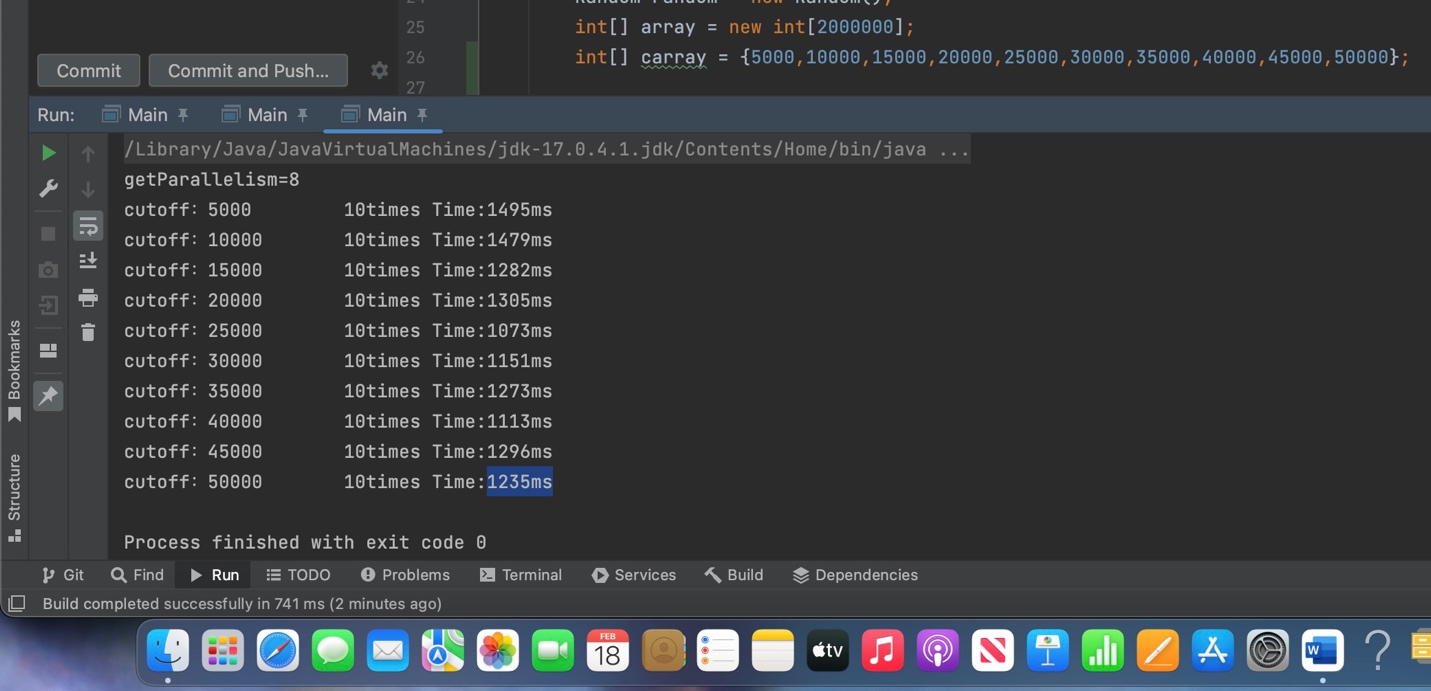
Array size : 2000000

A screenshot of a computer

Description automatically generated

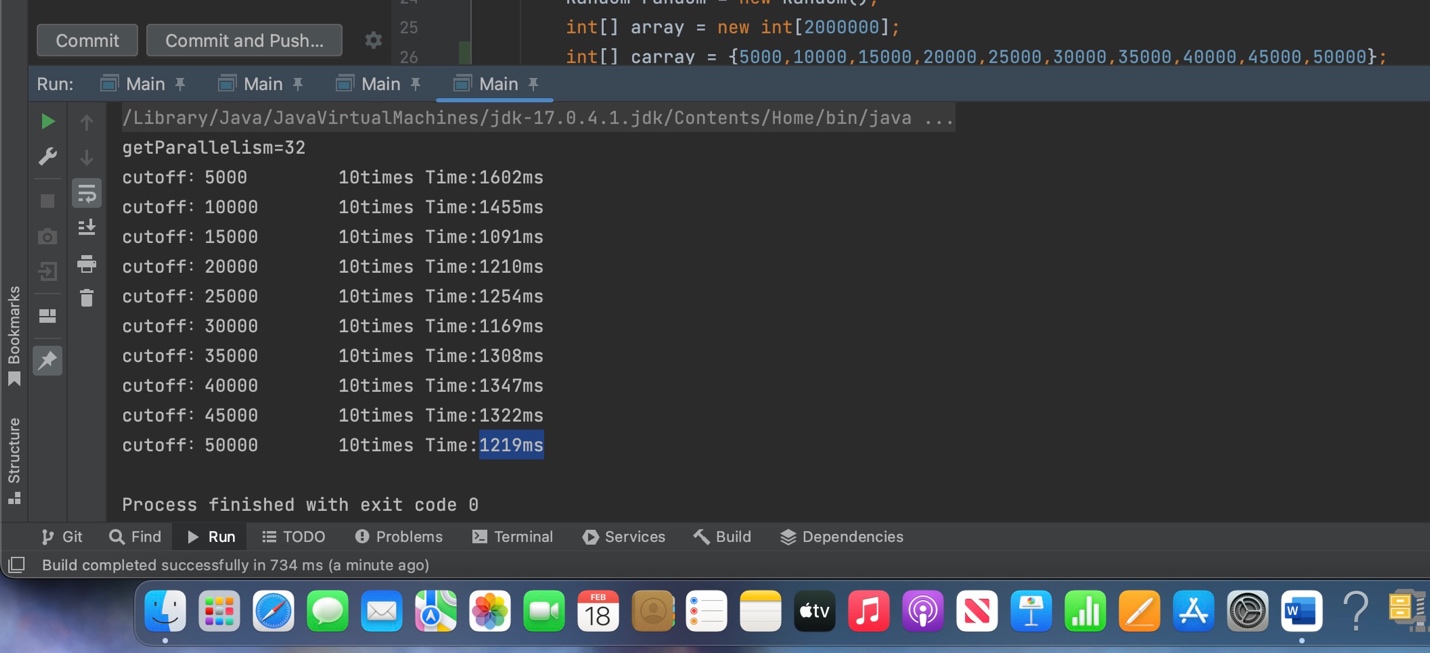
Graphical user interface, text

Description automatically generated



Graphical user interface, text

Description automatically generated



Array size : 100000

Text

Description automatically generated

Text

Description automatically generated

Graphical user interface, text

Description automatically generated

Text

Description automatically generated

Text

Description automatically generated

Array size : 50000

Text

Description automatically generated

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Description automatically generated

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Description automatically generated