INFO 6205 Program Structures & Algorithms Spring 2022

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Assignment No. 5

Task: To implement a parallel sorting algorithm such that each partition of the array is sorted in parallel. Considering two different schemes for deciding whether to sort in parallel

- Cutoff (defaults to, say, 1000) which will update according to the first argument in the command line when running.
- Recursion depth or the number of available threads. Using this determination, 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)

Show the results of experiments and draw a conclusion (or more) about the efficacy of this method of the parallelizing sort. The experiments should involve sorting arrays of sufficient size for the parallel sort to make a difference. Run with many different array sizes (they must be sufficiently large to make parallel sorting worthwhile) and different cutoff schemes

- **OUTPUT**

Size of Array: 50000

Degree of parallelism: 2

cutoff：5000	10times Time:121ms
cutoff：10000	10times Time:73ms
cutoff：15000	10times Time:71ms
cutoff：20000	10times Time:66ms
cutoff：25000	10times Time:27ms
cutoff：30000	10times Time:48ms
cutoff：35000	10times Time:45ms
cutoff：40000	10times Time:63ms
cutoff：45000	10times Time:25ms
cutoff：50000	10times Time:27ms

Degree of parallelism: 4

cutoff：5000 10times Time:35ms
cutoff：10000 10times Time:23ms
cutoff：15000 10times Time:21ms
cutoff：20000 10times Time:21ms
cutoff：25000 10times Time:21ms
cutoff：30000 10times Time:25ms
cutoff：35000 10times Time:28ms
cutoff：40000 10times Time:26ms
cutoff：45000 10times Time:23ms
cutoff：50000 10times Time:27ms
Degree of parallelism: 8
cutoff：5000 10times Time:30ms
cutoff：10000 10times Time:21ms
cutoff：15000 10times Time:19ms
cutoff：20000 10times Time:18ms
cutoff：25000 10times Time:18ms
cutoff：30000 10times Time:23ms
cutoff：35000 10times Time:27ms
cutoff：40000 10times Time:23ms
cutoff：45000 10times Time:23ms
cutoff：50000 10times Time:23ms
Degree of parallelism: 16
cutoff：5000 10times Time:25ms
cutoff：10000 10times Time:23ms
cutoff：15000 10times Time:23ms
cutoff：20000 10times Time:23ms
cutoff：25000 10times Time:23ms
cutoff：30000 10times Time:24ms
cutoff：35000 10times Time:25ms
cutoff：40000 10times Time:24ms
cutoff：45000 10times Time:26ms
cutoff：50000 10times Time:23ms
Degree of parallelism: 32
cutoff：5000 10times Time:27ms
cutoff：10000 10times Time:24ms
cutoff：15000 10times Time:24ms
cutoff：20000 10times Time:23ms
cutoff：25000 10times Time:22ms

cutoff：30000 10times Time:24ms
cutoff：35000 10times Time:23ms
cutoff：40000 10times Time:24ms
cutoff：45000 10times Time:23ms
cutoff：50000 10times Time:25ms
Degree of parallelism: 64
cutoff：5000 10times Time:27ms
cutoff：10000 10times Time:20ms
cutoff：15000 10times Time:20ms
cutoff：20000 10times Time:21ms
cutoff：25000 10times Time:20ms
cutoff：30000 10times Time:25ms
cutoff：35000 10times Time:21ms
cutoff：40000 10times Time:25ms
cutoff：45000 10times Time:25ms
cutoff：50000 10times Time:24ms

Process finished with exit code 0

Size of Array: 100000
Degree of parallelism: 2
cutoff：5000 10times Time:173ms
cutoff：10000 10times Time:122ms
cutoff：15000 10times Time:56ms
cutoff：20000 10times Time:89ms
cutoff：25000 10times Time:94ms
cutoff：30000 10times Time:121ms
cutoff：35000 10times Time:57ms
cutoff：40000 10times Time:52ms
cutoff：45000 10times Time:57ms
cutoff：50000 10times Time:54ms
Degree of parallelism: 4
cutoff：5000 10times Time:56ms
cutoff：10000 10times Time:43ms
cutoff：15000 10times Time:44ms
cutoff：20000 10times Time:42ms
cutoff：25000 10times Time:40ms
cutoff：30000 10times Time:36ms

cutoff：35000 10times Time:39ms
cutoff：40000 10times Time:38ms
cutoff：45000 10times Time:38ms
cutoff：50000 10times Time:35ms
Degree of parallelism: 8
cutoff：5000 10times Time:59ms
cutoff：10000 10times Time:36ms
cutoff：15000 10times Time:36ms
cutoff：20000 10times Time:35ms
cutoff：25000 10times Time:37ms
cutoff：30000 10times Time:41ms
cutoff：35000 10times Time:40ms
cutoff：40000 10times Time:43ms
cutoff：45000 10times Time:41ms
cutoff：50000 10times Time:41ms
Degree of parallelism: 16
cutoff：5000 10times Time:49ms
cutoff：10000 10times Time:41ms
cutoff：15000 10times Time:38ms
cutoff：20000 10times Time:37ms
cutoff：25000 10times Time:34ms
cutoff：30000 10times Time:37ms
cutoff：35000 10times Time:38ms
cutoff：40000 10times Time:39ms
cutoff：45000 10times Time:39ms
cutoff：50000 10times Time:40ms
Degree of parallelism: 32
cutoff：5000 10times Time:41ms
cutoff：10000 10times Time:35ms
cutoff：15000 10times Time:37ms
cutoff：20000 10times Time:36ms
cutoff：25000 10times Time:39ms
cutoff：30000 10times Time:41ms
cutoff：35000 10times Time:38ms
cutoff：40000 10times Time:36ms
cutoff：45000 10times Time:37ms
cutoff：50000 10times Time:39ms
Degree of parallelism: 64

cutoff：5000 10times Time:44ms
cutoff：10000 10times Time:40ms
cutoff：15000 10times Time:36ms
cutoff：20000 10times Time:38ms
cutoff：25000 10times Time:35ms
cutoff：30000 10times Time:40ms
cutoff：35000 10times Time:41ms
cutoff：40000 10times Time:42ms
cutoff：45000 10times Time:39ms
cutoff：50000 10times Time:37ms

Process finished with exit code 0

Size of Array: 200000

Degree of parallelism: 2
cutoff：5000 10times Time:244ms
cutoff：10000 10times Time:170ms
cutoff：15000 10times Time:135ms
cutoff：20000 10times Time:135ms
cutoff：25000 10times Time:92ms
cutoff：30000 10times Time:110ms
cutoff：35000 10times Time:155ms
cutoff：40000 10times Time:96ms
cutoff：45000 10times Time:90ms
cutoff：50000 10times Time:91ms
Degree of parallelism: 4
cutoff：5000 10times Time:102ms
cutoff：10000 10times Time:79ms
cutoff：15000 10times Time:87ms
cutoff：20000 10times Time:76ms
cutoff：25000 10times Time:74ms
cutoff：30000 10times Time:80ms
cutoff：35000 10times Time:80ms
cutoff：40000 10times Time:79ms
cutoff：45000 10times Time:79ms
cutoff：50000 10times Time:77ms
Degree of parallelism: 8
cutoff：5000 10times Time:87ms

cutoff：10000 10times Time:82ms
cutoff：15000 10times Time:71ms
cutoff：20000 10times Time:81ms
cutoff：25000 10times Time:110ms
cutoff：30000 10times Time:71ms
cutoff：35000 10times Time:69ms
cutoff：40000 10times Time:74ms
cutoff：45000 10times Time:126ms
cutoff：50000 10times Time:179ms
Degree of parallelism: 16
cutoff：5000 10times Time:220ms
cutoff：10000 10times Time:174ms
cutoff：15000 10times Time:180ms
cutoff：20000 10times Time:176ms
cutoff：25000 10times Time:171ms
cutoff：30000 10times Time:165ms
cutoff：35000 10times Time:169ms
cutoff：40000 10times Time:169ms
cutoff：45000 10times Time:165ms
cutoff：50000 10times Time:167ms
Degree of parallelism: 32
cutoff：5000 10times Time:213ms
cutoff：10000 10times Time:169ms
cutoff：15000 10times Time:167ms
cutoff：20000 10times Time:167ms
cutoff：25000 10times Time:170ms
cutoff：30000 10times Time:171ms
cutoff：35000 10times Time:179ms
cutoff：40000 10times Time:169ms
cutoff：45000 10times Time:164ms
cutoff：50000 10times Time:166ms
Degree of parallelism: 64
cutoff：5000 10times Time:183ms
cutoff：10000 10times Time:163ms
cutoff：15000 10times Time:174ms
cutoff：20000 10times Time:176ms
cutoff：25000 10times Time:178ms
cutoff：30000 10times Time:170ms

cutoff : 35000 10times Time:168ms

cutoff : 40000 10times Time:172ms

cutoff : 45000 10times Time:172ms

cutoff : 50000 10times Time:169ms

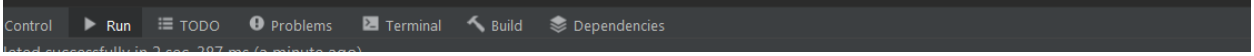
Process finished with exit code 0

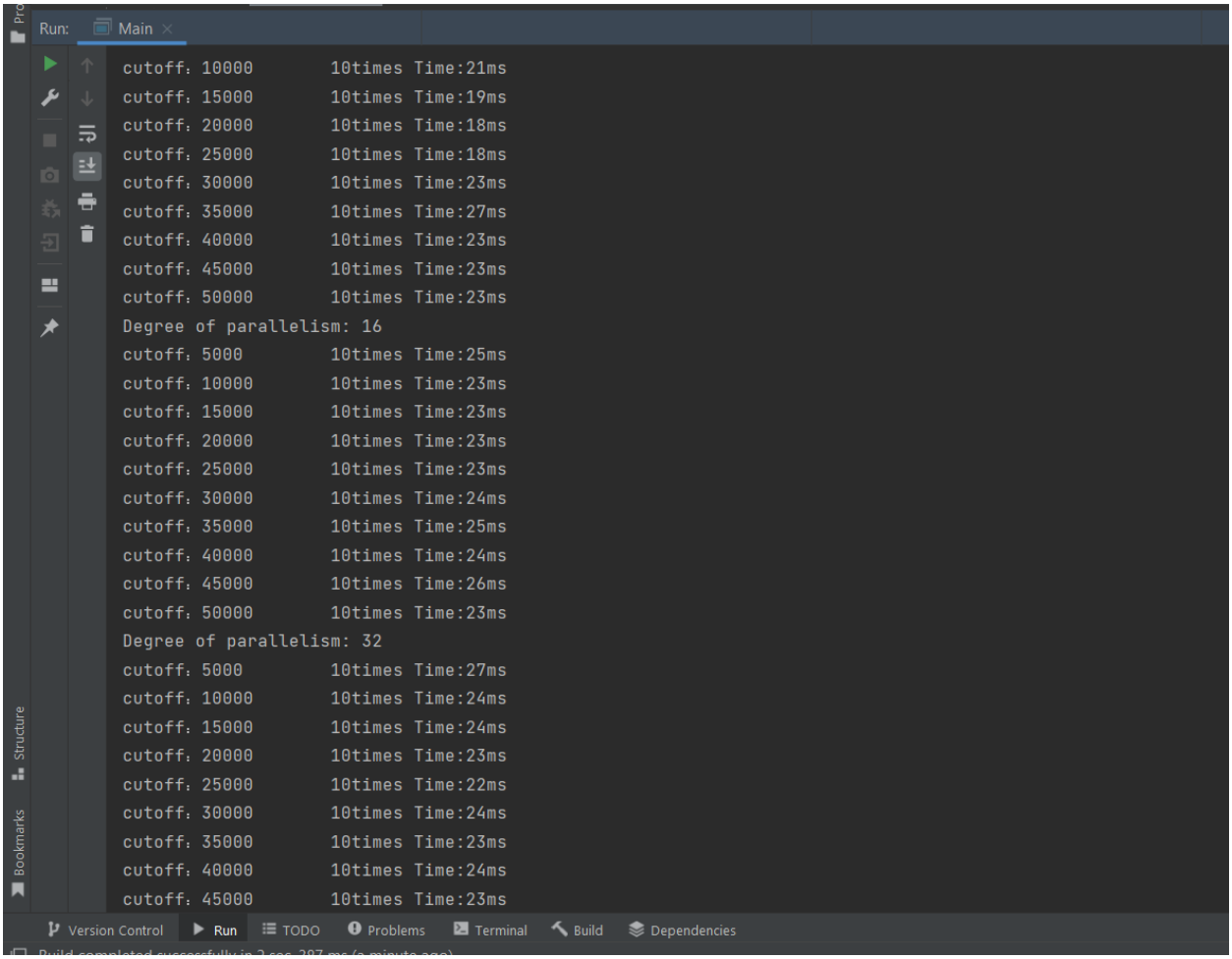
Relationship Conclusion: Conclusion can be made from the results mentioned above and the graphs that-

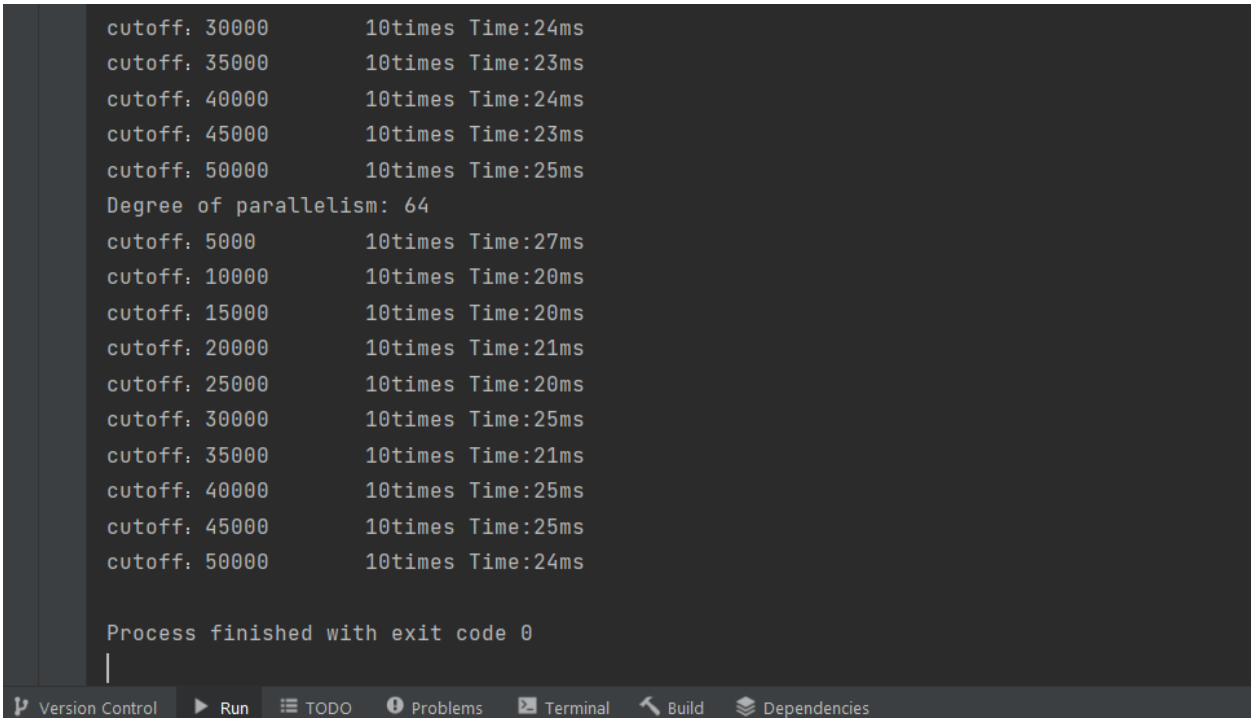
- After constant changing of cutoff value and the number of threads for variant sizes of arrays, the number of threads that are greater than 4 does not improve the performance. So, a number of threads = 4 is the optimal choice.
- Referring to the graph, it can be stated that the lowest performance time is achieved for the cutoff value which is 25% of the size of the array.
- Hence, to conclude the cutoff value as 25% and the number of threads equal to 4 as the optimization can be observed

Evidence to support Relationship:

```
Size of Array: 50000
Degree of parallelism: 2
cutoff: 5000        10times Time:121ms
cutoff: 10000       10times Time:73ms
cutoff: 15000       10times Time:71ms
cutoff: 20000       10times Time:66ms
cutoff: 25000       10times Time:27ms
cutoff: 30000       10times Time:48ms
cutoff: 35000       10times Time:45ms
cutoff: 40000       10times Time:63ms
cutoff: 45000       10times Time:25ms
cutoff: 50000       10times Time:27ms
Degree of parallelism: 4
cutoff: 5000        10times Time:35ms
cutoff: 10000       10times Time:23ms
cutoff: 15000       10times Time:21ms
cutoff: 20000       10times Time:21ms
cutoff: 25000       10times Time:21ms
cutoff: 30000       10times Time:25ms
cutoff: 35000       10times Time:28ms
cutoff: 40000       10times Time:26ms
cutoff: 45000       10times Time:23ms
cutoff: 50000       10times Time:27ms
Degree of parallelism: 8
cutoff: 5000        10times Time:30ms
cutoff: 10000       10times Time:21ms
cutoff: 15000       10times Time:19ms
cutoff: 20000       10times Time:18ms
cutoff: 25000       10times Time:18ms
```




Run:
Main
cutoff: 10000 10times Time:21ms
cutoff: 15000 10times Time:19ms
cutoff: 20000 10times Time:18ms
cutoff: 25000 10times Time:18ms
cutoff: 30000 10times Time:23ms
cutoff: 35000 10times Time:27ms
cutoff: 40000 10times Time:23ms
cutoff: 45000 10times Time:23ms
cutoff: 50000 10times Time:23ms
Degree of parallelism: 16
cutoff: 5000 10times Time:25ms
cutoff: 10000 10times Time:23ms
cutoff: 15000 10times Time:23ms
cutoff: 20000 10times Time:23ms
cutoff: 25000 10times Time:23ms
cutoff: 30000 10times Time:24ms
cutoff: 35000 10times Time:25ms
cutoff: 40000 10times Time:24ms
cutoff: 45000 10times Time:26ms
cutoff: 50000 10times Time:23ms
Degree of parallelism: 32
cutoff: 5000 10times Time:27ms
cutoff: 10000 10times Time:24ms
cutoff: 15000 10times Time:24ms
cutoff: 20000 10times Time:23ms
cutoff: 25000 10times Time:22ms
cutoff: 30000 10times Time:24ms
cutoff: 35000 10times Time:23ms
cutoff: 40000 10times Time:24ms
cutoff: 45000 10times Time:23ms
Structure
Bookmarks
Version Control
Run
TODO
Problems
Terminal
Build
Dependencies


cutoff: 30000 10times Time:24ms
cutoff: 35000 10times Time:23ms
cutoff: 40000 10times Time:24ms
cutoff: 45000 10times Time:23ms
cutoff: 50000 10times Time:25ms
Degree of parallelism: 64
cutoff: 5000 10times Time:27ms
cutoff: 10000 10times Time:20ms
cutoff: 15000 10times Time:20ms
cutoff: 20000 10times Time:21ms
cutoff: 25000 10times Time:20ms
cutoff: 30000 10times Time:25ms
cutoff: 35000 10times Time:21ms
cutoff: 40000 10times Time:25ms
cutoff: 45000 10times Time:25ms
cutoff: 50000 10times Time:24ms
Process finished with exit code 0
Version Control
Run
TODO
Problems
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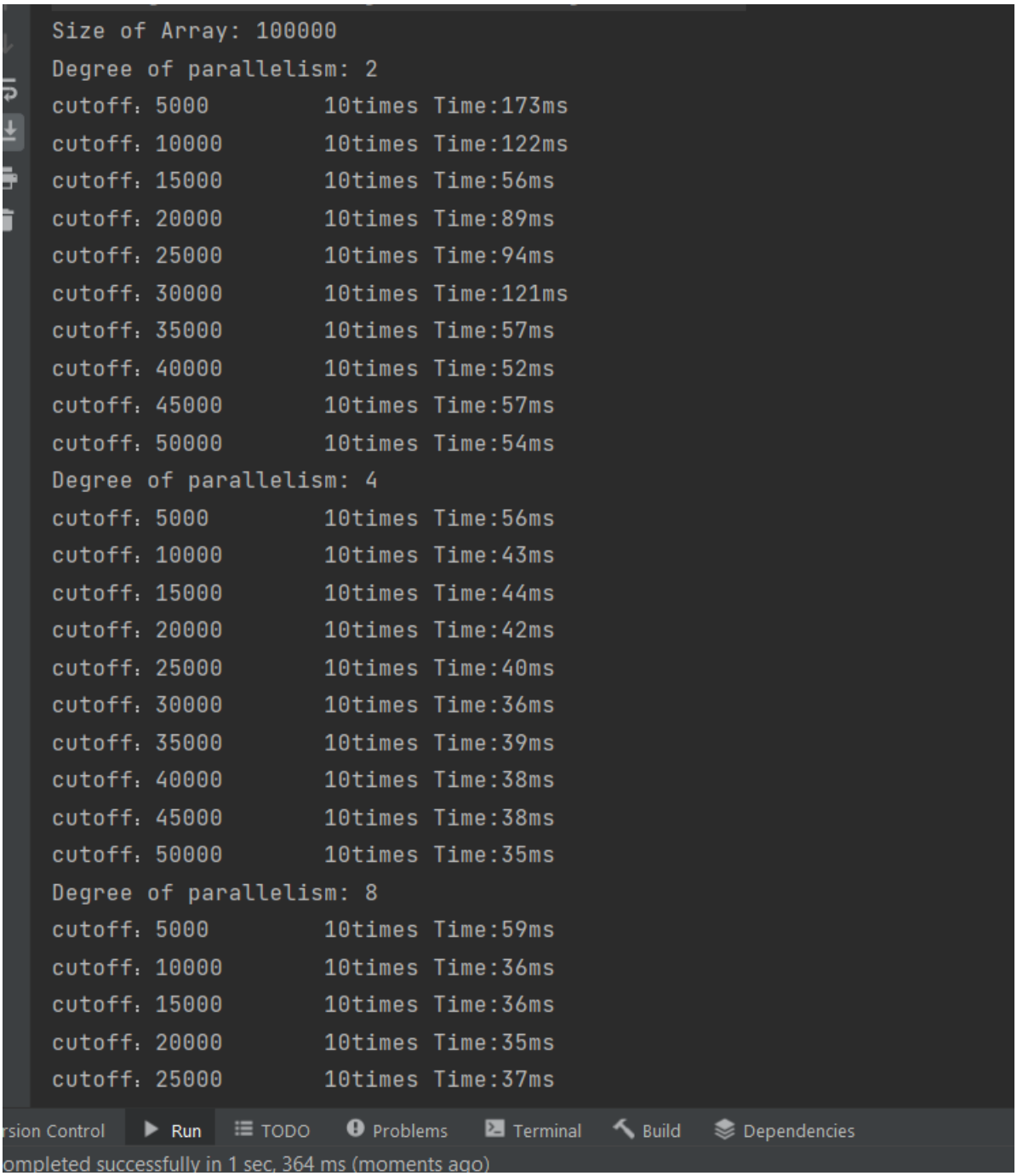
Dependencies


ArraySize = 100000
1200
1000
800
600
400
200
0
Time
0
10000
20000
30000
40000
50000
60000
Cut Off
2 Thread
4 Thread
8 Thread
16 Thread
32 Thread
64 Thread


Size of Array: 100000
Degree of parallelism: 2
cutoff: 5000 10times Time:173ms
cutoff: 10000 10times Time:122ms
cutoff: 15000 10times Time:56ms
cutoff: 20000 10times Time:89ms
cutoff: 25000 10times Time:94ms
cutoff: 30000 10times Time:121ms
cutoff: 35000 10times Time:57ms
cutoff: 40000 10times Time:52ms
cutoff: 45000 10times Time:57ms
cutoff: 50000 10times Time:54ms
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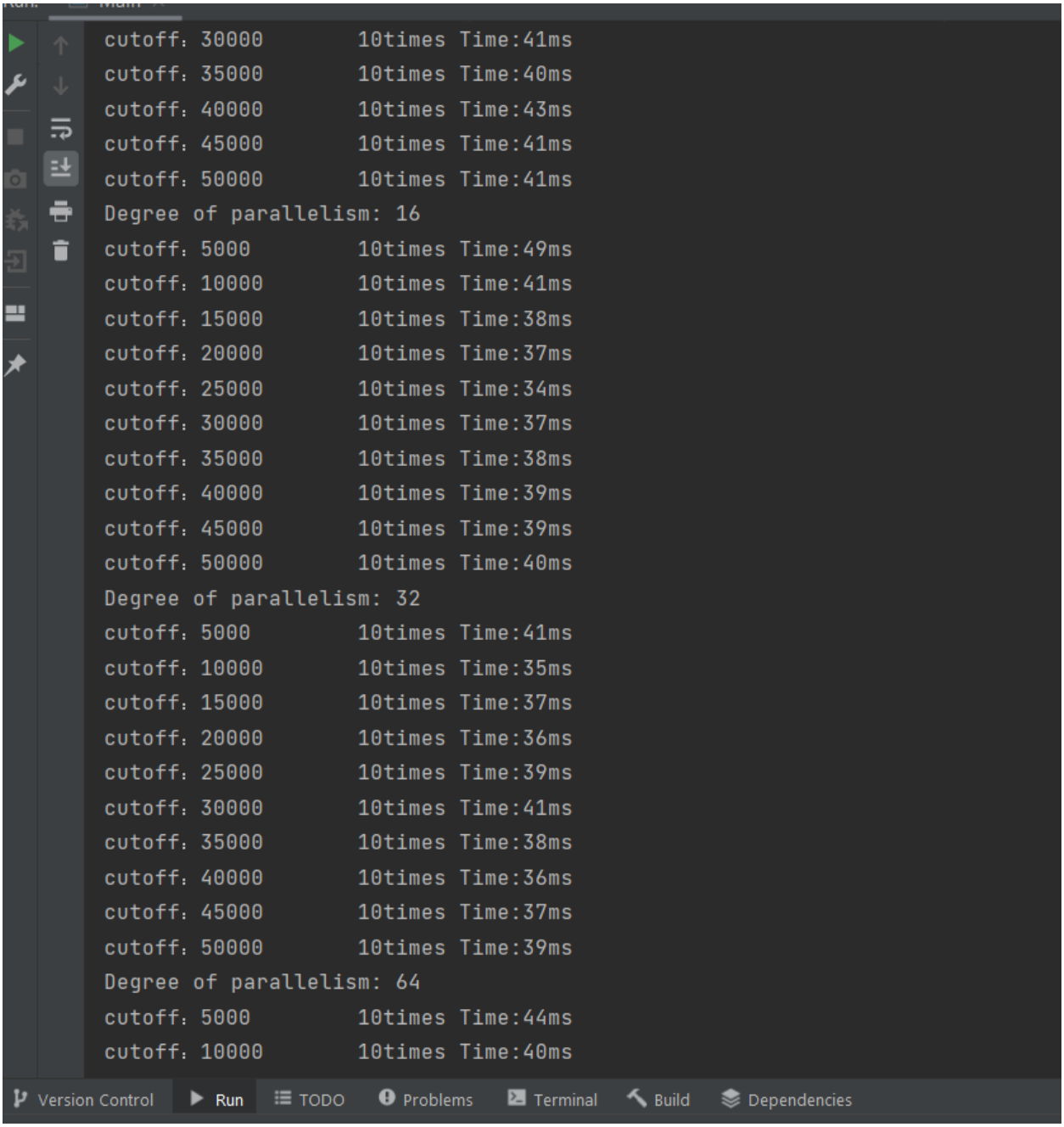
cutoff: 5000 10times Time:56ms
cutoff: 10000 10times Time:43ms
cutoff: 15000 10times Time:44ms
cutoff: 20000 10times Time:42ms
cutoff: 25000 10times Time:40ms
cutoff: 30000 10times Time:36ms
cutoff: 35000 10times Time:39ms
cutoff: 40000 10times Time:38ms
cutoff: 45000 10times Time:38ms
cutoff: 50000 10times Time:35ms
Degree of parallelism: 8
cutoff: 5000 10times Time:59ms
cutoff: 10000 10times Time:36ms
cutoff: 15000 10times Time:36ms
cutoff: 20000 10times Time:35ms
cutoff: 25000 10times Time:37ms
rsion Control
Run
TODO
Problems
Terminal
Build
Dependencies
ompleted successfully in 1 sec, 364 ms (moments ago)


cutoff: 30000 10times Time:41ms
cutoff: 35000 10times Time:40ms
cutoff: 40000 10times Time:43ms
cutoff: 45000 10times Time:41ms
cutoff: 50000 10times Time:41ms
Degree of parallelism: 16
cutoff: 5000 10times Time:49ms
cutoff: 10000 10times Time:41ms
cutoff: 15000 10times Time:38ms
cutoff: 20000 10times Time:37ms
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cutoff: 30000 10times Time:37ms
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cutoff: 45000 10times Time:39ms
cutoff: 50000 10times Time:40ms
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cutoff: 10000 10times Time:35ms
cutoff: 15000 10times Time:37ms
cutoff: 20000 10times Time:36ms
cutoff: 25000 10times Time:39ms
cutoff: 30000 10times Time:41ms
cutoff: 35000 10times Time:38ms
cutoff: 40000 10times Time:36ms
cutoff: 45000 10times Time:37ms
cutoff: 50000 10times Time:39ms
Degree of parallelism: 64
cutoff: 5000 10times Time:44ms
cutoff: 10000 10times Time:40ms
Version Control
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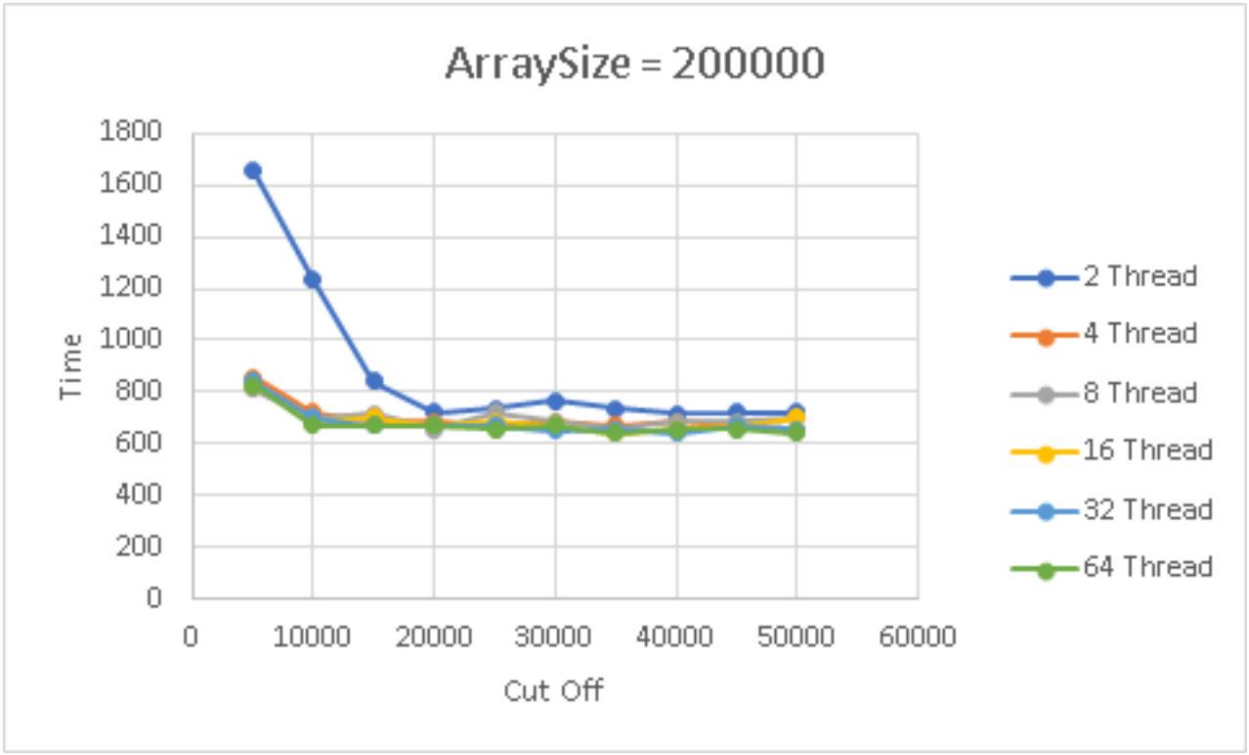
TODO
Problems
Terminal
Build
Dependencies

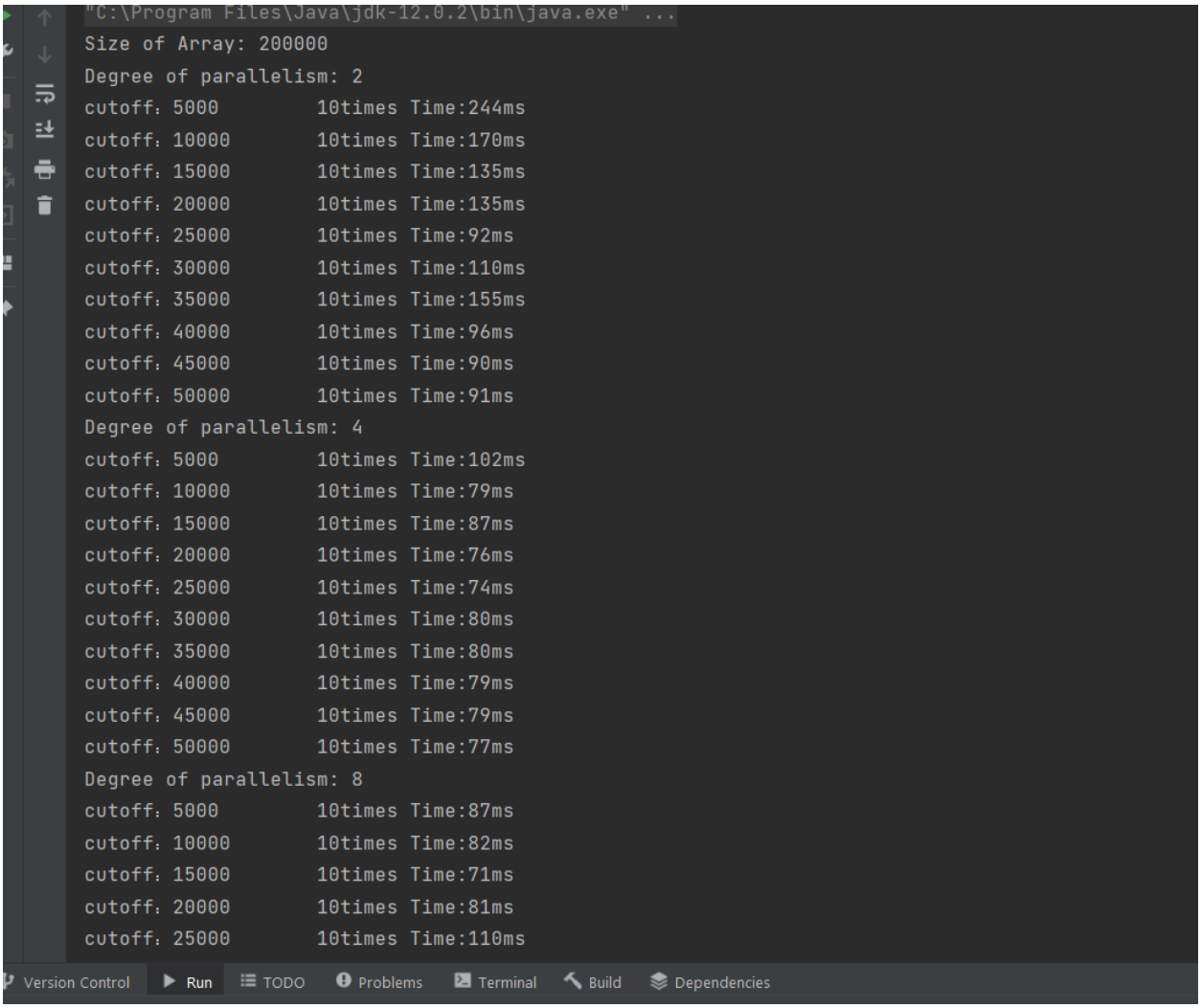
```
Degree of parallelism: 64
cutoff: 5000        10times Time:44ms
cutoff: 10000       10times Time:40ms
cutoff: 15000       10times Time:36ms
cutoff: 20000       10times Time:38ms
cutoff: 25000       10times Time:35ms
cutoff: 30000       10times Time:40ms
cutoff: 35000       10times Time:41ms
cutoff: 40000       10times Time:42ms
cutoff: 45000       10times Time:39ms
cutoff: 50000       10times Time:37ms

Process finished with exit code 0
```

sion Control | Run | TODO | Problems | Terminal | Build | Dependencies

mpleted successfully in 1 sec, 364 ms (a minute ago)




"C:\Program Files\Java\jdk-12.0.2\bin\java.exe" ...
Size of Array: 200000
Degree of parallelism: 2
cutoff: 5000 10times Time:244ms
cutoff: 10000 10times Time:170ms
cutoff: 15000 10times Time:135ms
cutoff: 20000 10times Time:135ms
cutoff: 25000 10times Time:92ms
cutoff: 30000 10times Time:110ms
cutoff: 35000 10times Time:155ms
cutoff: 40000 10times Time:96ms
cutoff: 45000 10times Time:90ms
cutoff: 50000 10times Time:91ms
Degree of parallelism: 4
cutoff: 5000 10times Time:102ms
cutoff: 10000 10times Time:79ms
cutoff: 15000 10times Time:87ms
cutoff: 20000 10times Time:76ms
cutoff: 25000 10times Time:74ms
cutoff: 30000 10times Time:80ms
cutoff: 35000 10times Time:80ms
cutoff: 40000 10times Time:79ms
cutoff: 45000 10times Time:79ms
cutoff: 50000 10times Time:77ms
Degree of parallelism: 8
cutoff: 5000 10times Time:87ms
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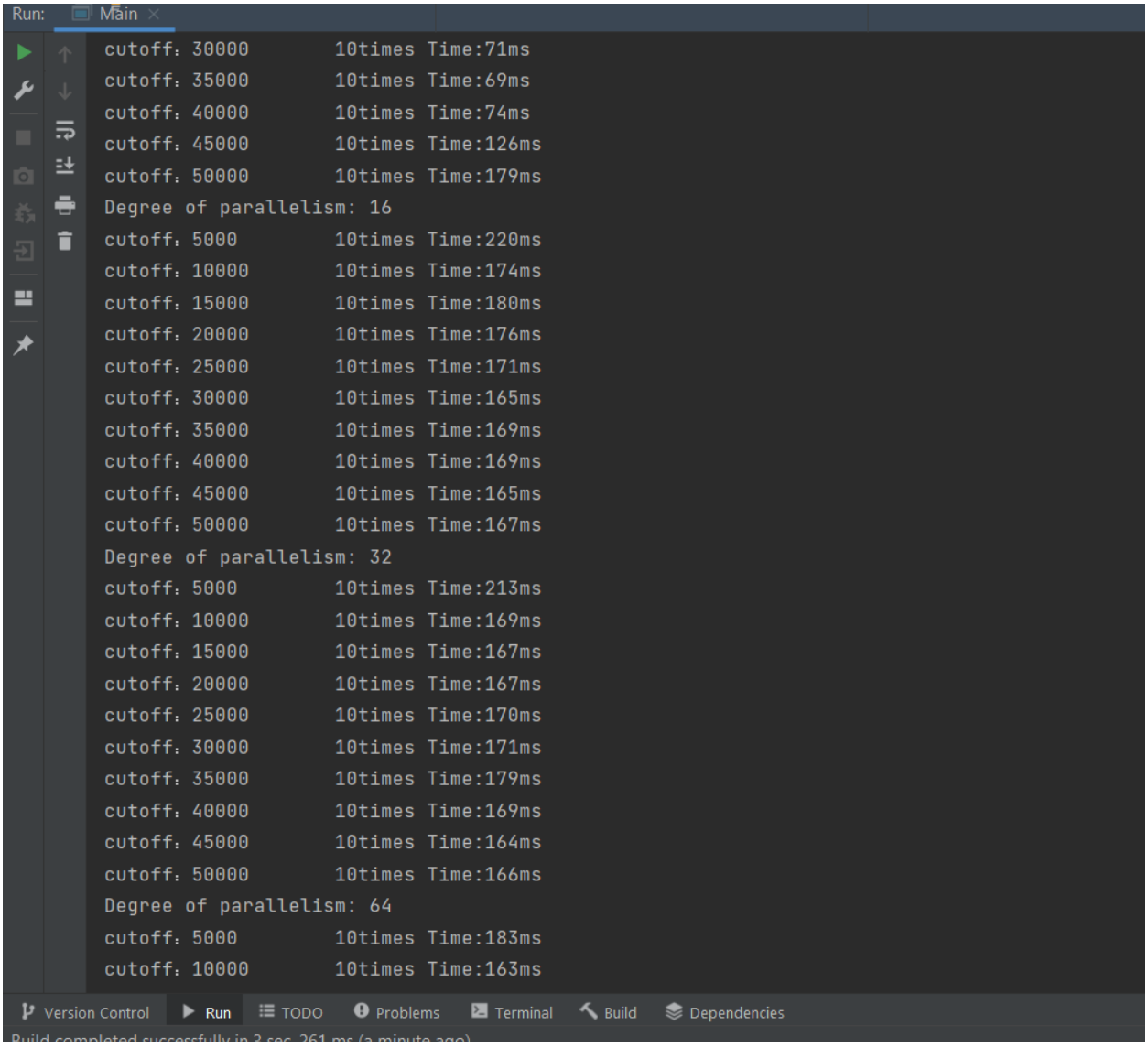
Version Control
Run
TODO
Problems
Terminal
Build
Dependencies


Run:
Main
cutoff: 30000 10times Time:71ms
cutoff: 35000 10times Time:69ms
cutoff: 40000 10times Time:74ms
cutoff: 45000 10times Time:126ms
cutoff: 50000 10times Time:179ms
Degree of parallelism: 16
cutoff: 5000 10times Time:220ms
cutoff: 10000 10times Time:174ms
cutoff: 15000 10times Time:180ms
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cutoff: 25000 10times Time:171ms
cutoff: 30000 10times Time:165ms
cutoff: 35000 10times Time:169ms
cutoff: 40000 10times Time:169ms
cutoff: 45000 10times Time:165ms
cutoff: 50000 10times Time:167ms
Degree of parallelism: 32
cutoff: 5000 10times Time:213ms
cutoff: 10000 10times Time:169ms
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cutoff: 40000 10times Time:169ms
cutoff: 45000 10times Time:164ms
cutoff: 50000 10times Time:166ms
Degree of parallelism: 64
cutoff: 5000 10times Time:183ms
cutoff: 10000 10times Time:163ms
Version Control
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TODO
Problems
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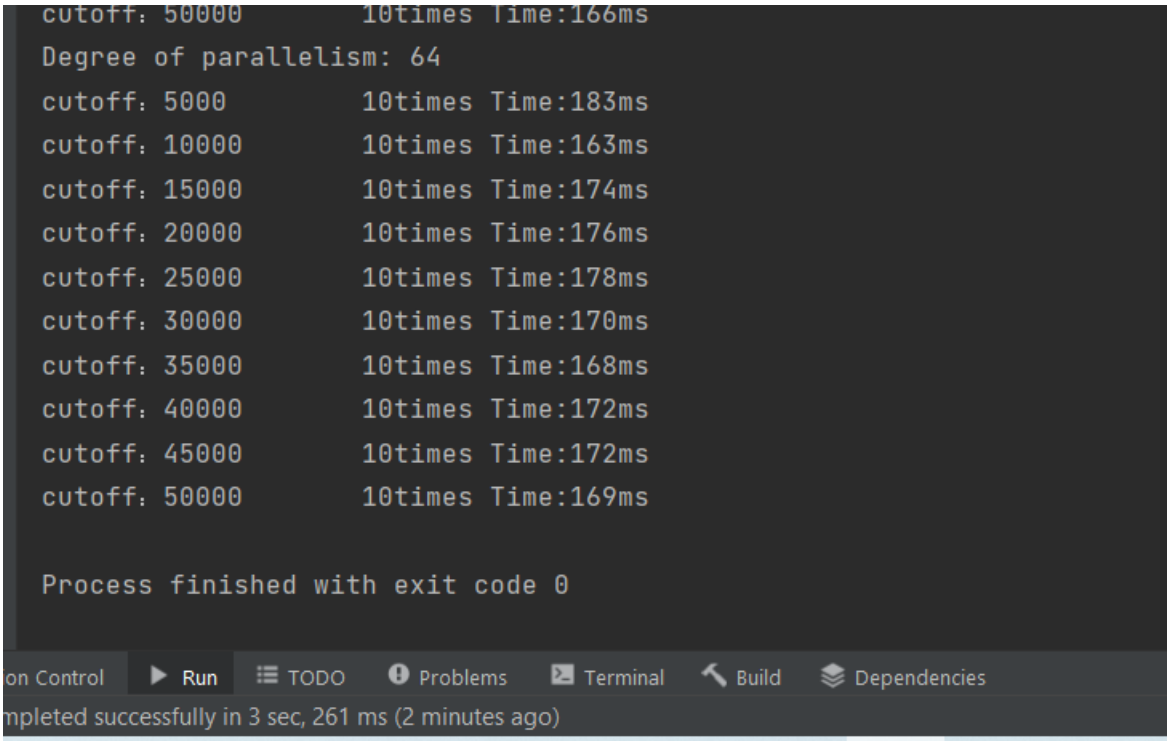
Dependencies


cutoff: 50000 10times Time:166ms
Degree of parallelism: 64
cutoff: 5000 10times Time:183ms
cutoff: 10000 10times Time:163ms
cutoff: 15000 10times Time:174ms
cutoff: 20000 10times Time:176ms
cutoff: 25000 10times Time:178ms
cutoff: 30000 10times Time:170ms
cutoff: 35000 10times Time:168ms
cutoff: 40000 10times Time:172ms
cutoff: 45000 10times Time:172ms
cutoff: 50000 10times Time:169ms
Process finished with exit code 0
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TODO
Problems
Terminal
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mpleted successfully in 3 sec, 261 ms (2 minutes ago)