Program Structures and Algorithms
Fall 2023

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Task:

Please see the presentation on *Assignment on Parallel Sorting* under the *Exams. etc.* module.
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.

There is a *Main* class and the *ParSort* class in the *sort.par* package of the INFO6205 repository. The *Main* class can be used as is but the *ParSort* class needs to be implemented where you see "TODO..." [it turns out that these TODOs are already implemented].
Unless you have a good reason not to, you should just go along with the Java8-style future implementations provided for you in the class repository.
You must prepare a report that shows the results of your experiments and draws a conclusion (or more) about the efficacy of this method of parallelizing sort. Your experiments should involve sorting arrays of sufficient size for the parallel sort to make a difference. You should run with many different array sizes (they must be sufficiently large to make parallel sorting worthwhile, obviously) and different cutoff schemes.

Relationship Conclusion:

After conducting a series of experiments involving varying array sizes and thread numbers, it was found that 8 threads provide the most optimal performance for my system. Beyond this point, increasing the number of threads did not lead to significant improvements in results. Additionally, the experiments indicated that the most efficient sorting times were consistently achieved when using a cutoff value within the range of 10% to 20% of the array size. Specifically, a cutoff value of approximately 15% of the array size consistently yielded the best results. Therefore, it can be concluded that a cutoff value representing about 15% of the array size is the optimal choice for this particular task.

Evidence to support that conclusion:

N = 1000000, Cutoff range from 50000 to 500000

	2	4	8	16	32	64
50000	886	411	421	363	303	288
100000	424	319	322	287	284	297
150000	488	323	274	278	318	329
200000	506	327	268	269	318	322
250000	411	337	265	275	351	318
300000	477	305	305	309	365	366
350000	453	301	305	319	323	345
400000	437	303	304	324	316	342
450000	459	309	304	324	315	362
500000	428	304	307	330	314	336

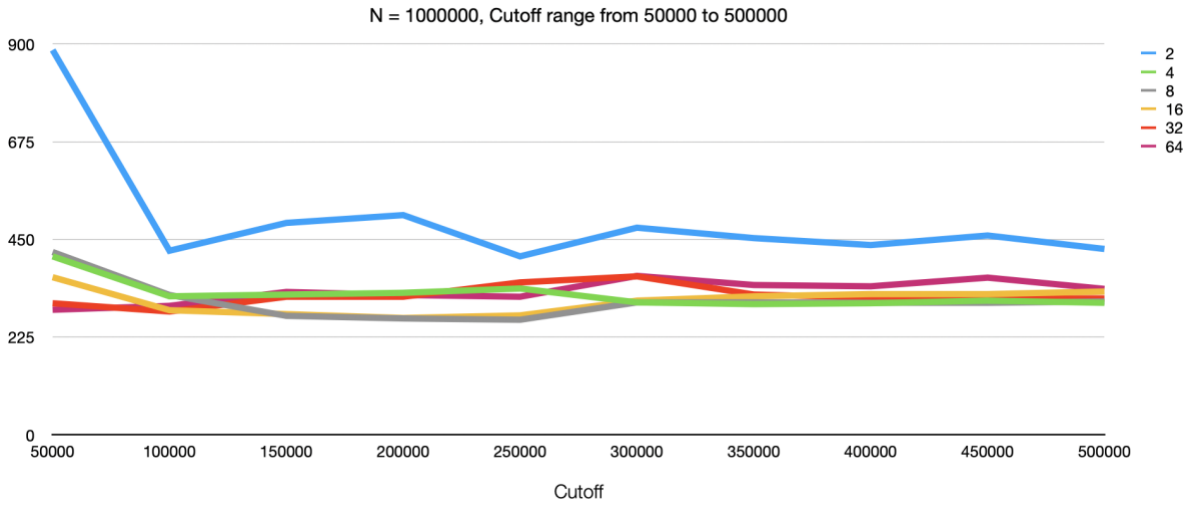
N = 2000000, Cutoff range from 100000 to 1000000

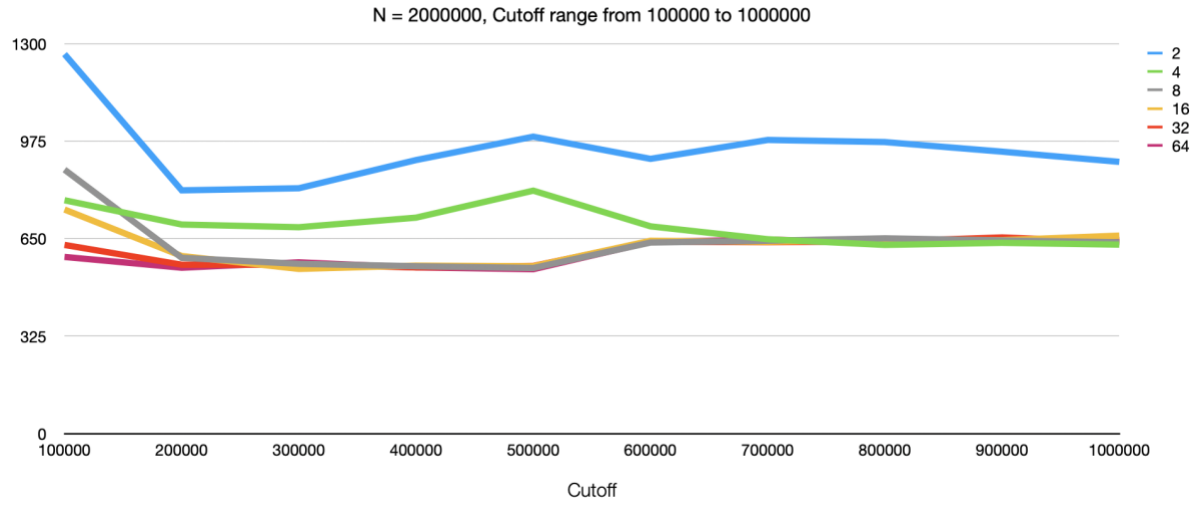
	2	4	8	16	32	64
100000	1265	778	880	747	629	589
200000	811	697	586	592	563	553
300000	818	688	566	549	563	571
400000	912	720	558	560	554	554
500000	990	810	552	558	559	548
600000	916	691	637	643	640	639
700000	979	648	643	639	638	647
800000	972	629	651	647	641	636
900000	940	636	644	645	654	643
1000000	906	630	638	660	639	645

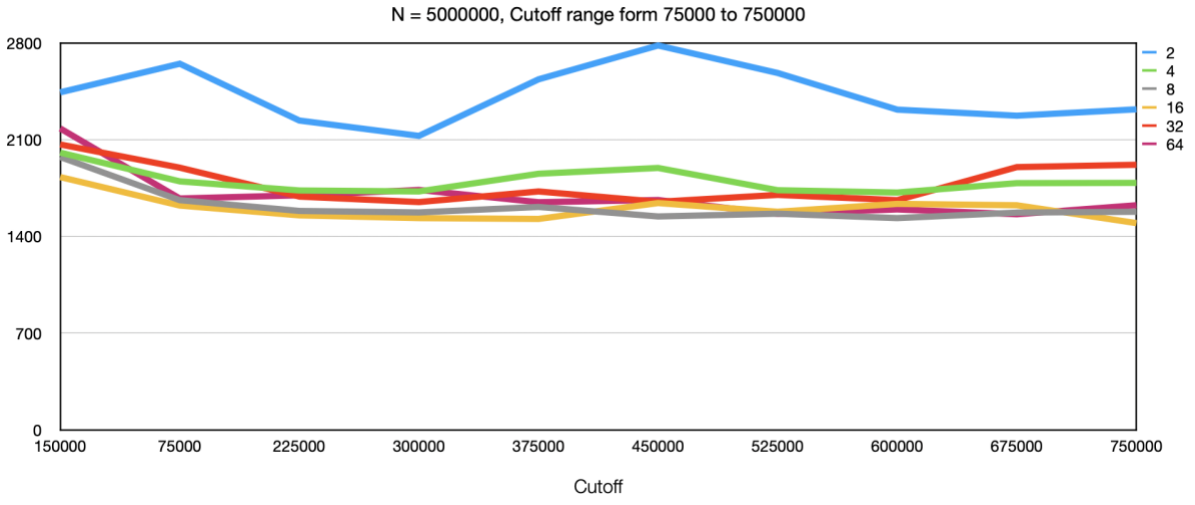
N = 5000000, Cutoff range form 75000 to 750000

	2	4	8	16	32	64
75000	2649	2006	1974	1829	2065	2181
150000	2442	1798	1662	1623	1897	1674
225000	2238	1732	1584	1552	1688	1697
300000	2127	1725	1573	1532	1648	1736
375000	2536	1853	1613	1526	1725	1647
450000	2781	1895	1544	1641	1650	1663
525000	2582	1734	1564	1578	1700	1563
600000	2317	1717	1532	1635	1662	1595
675000	2273	1785	1572	1625	1901	1560
750000	2319	1787	1578	1496	1918	1625

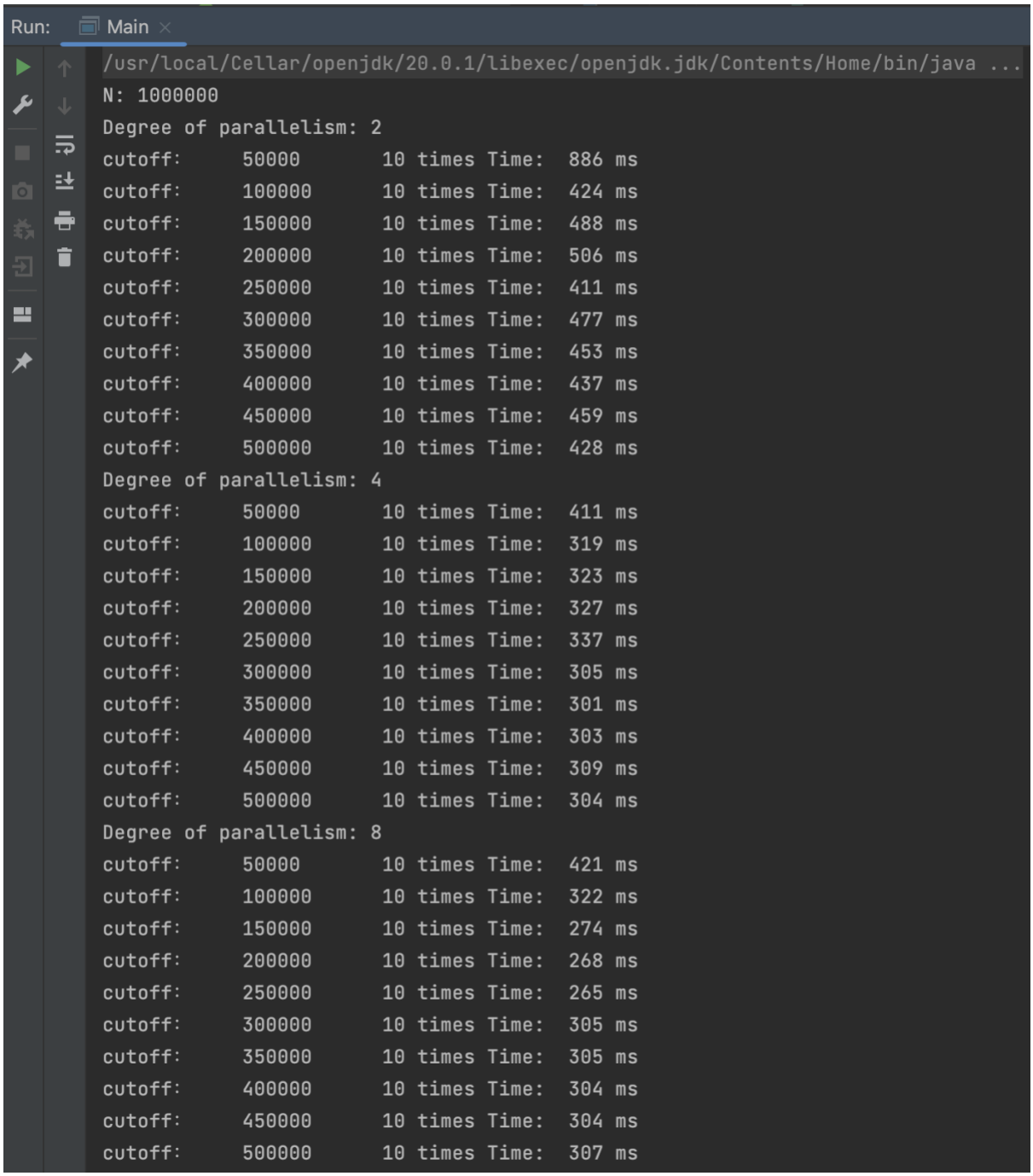
Graphical Representation:

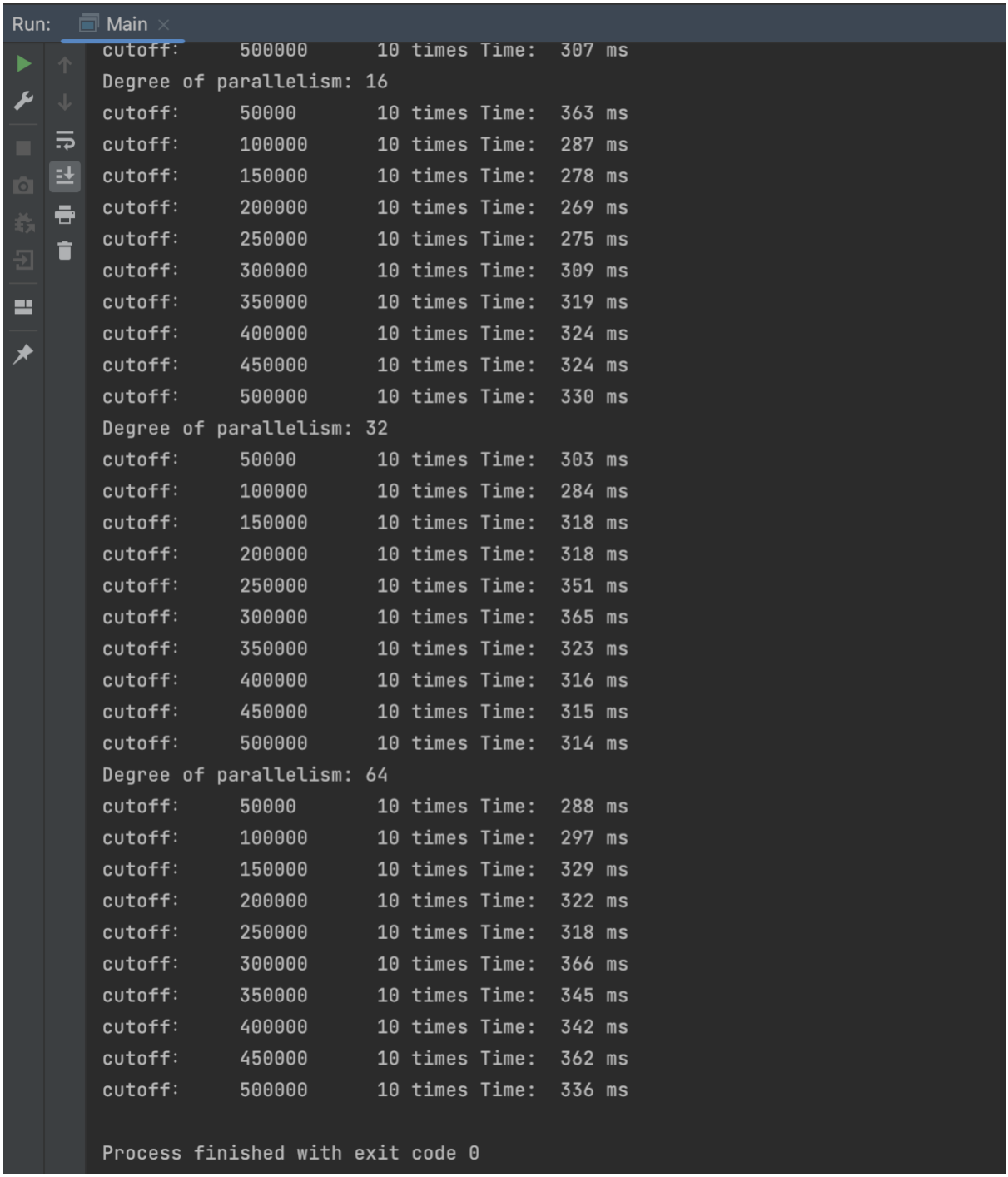


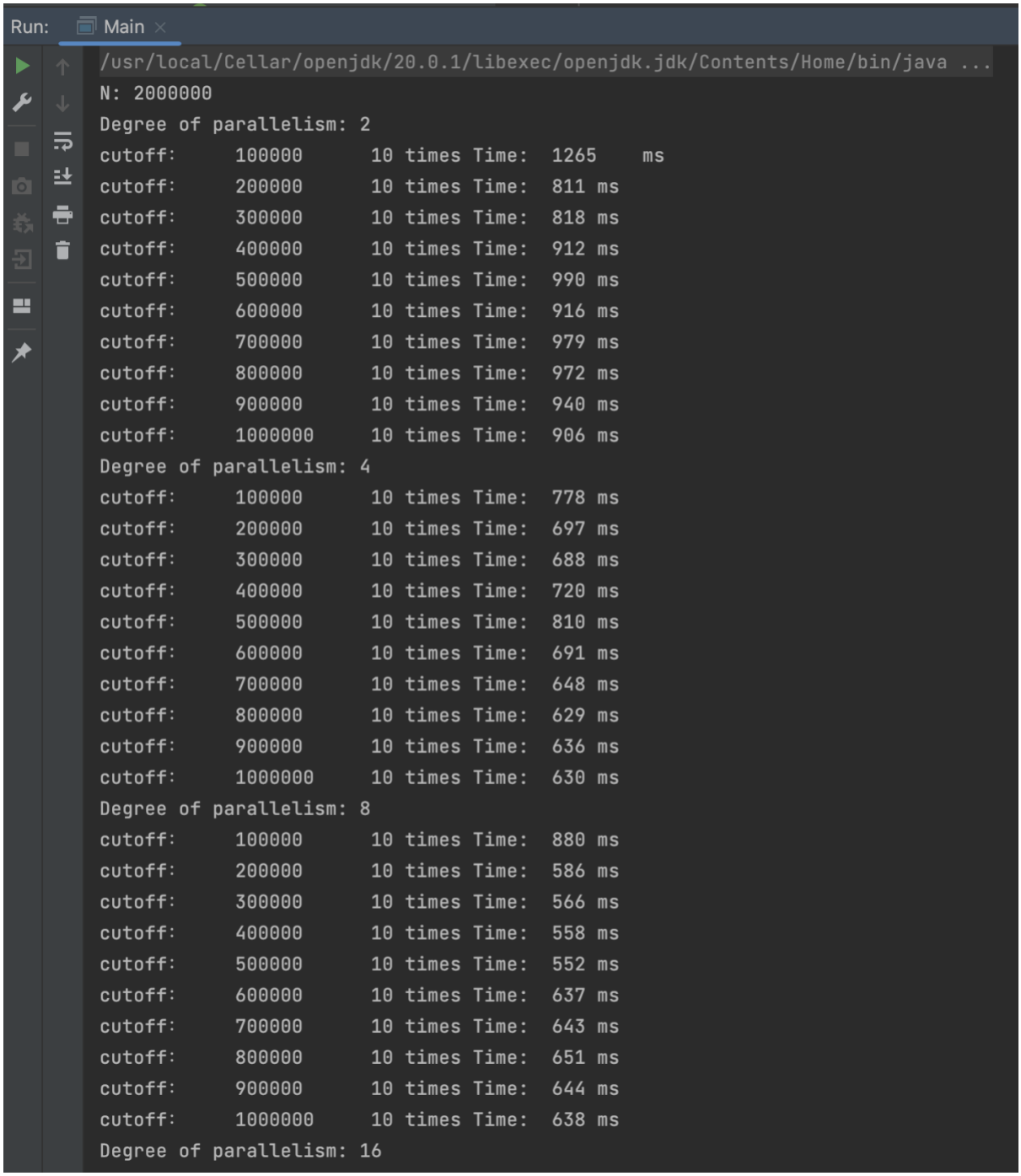


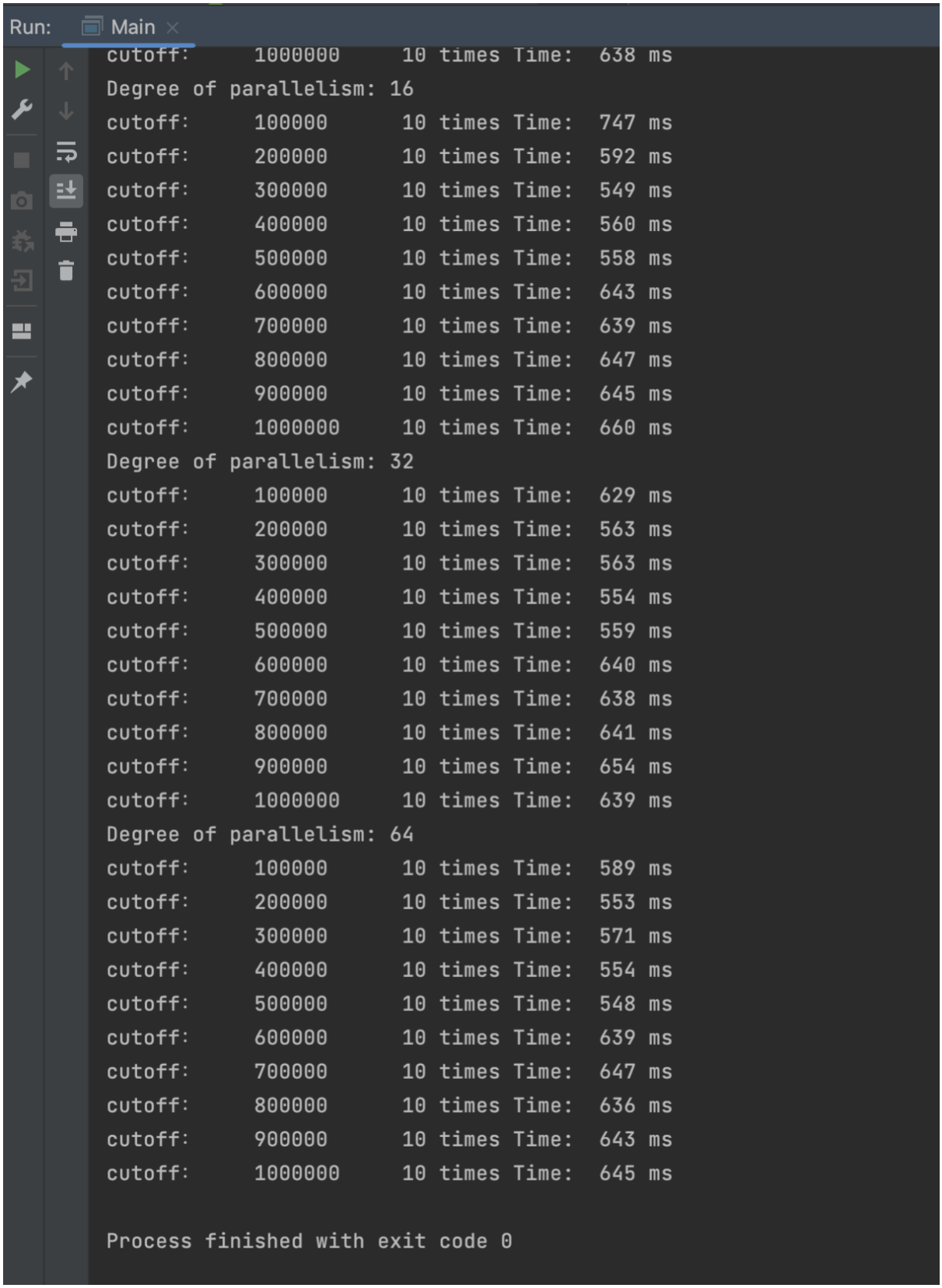


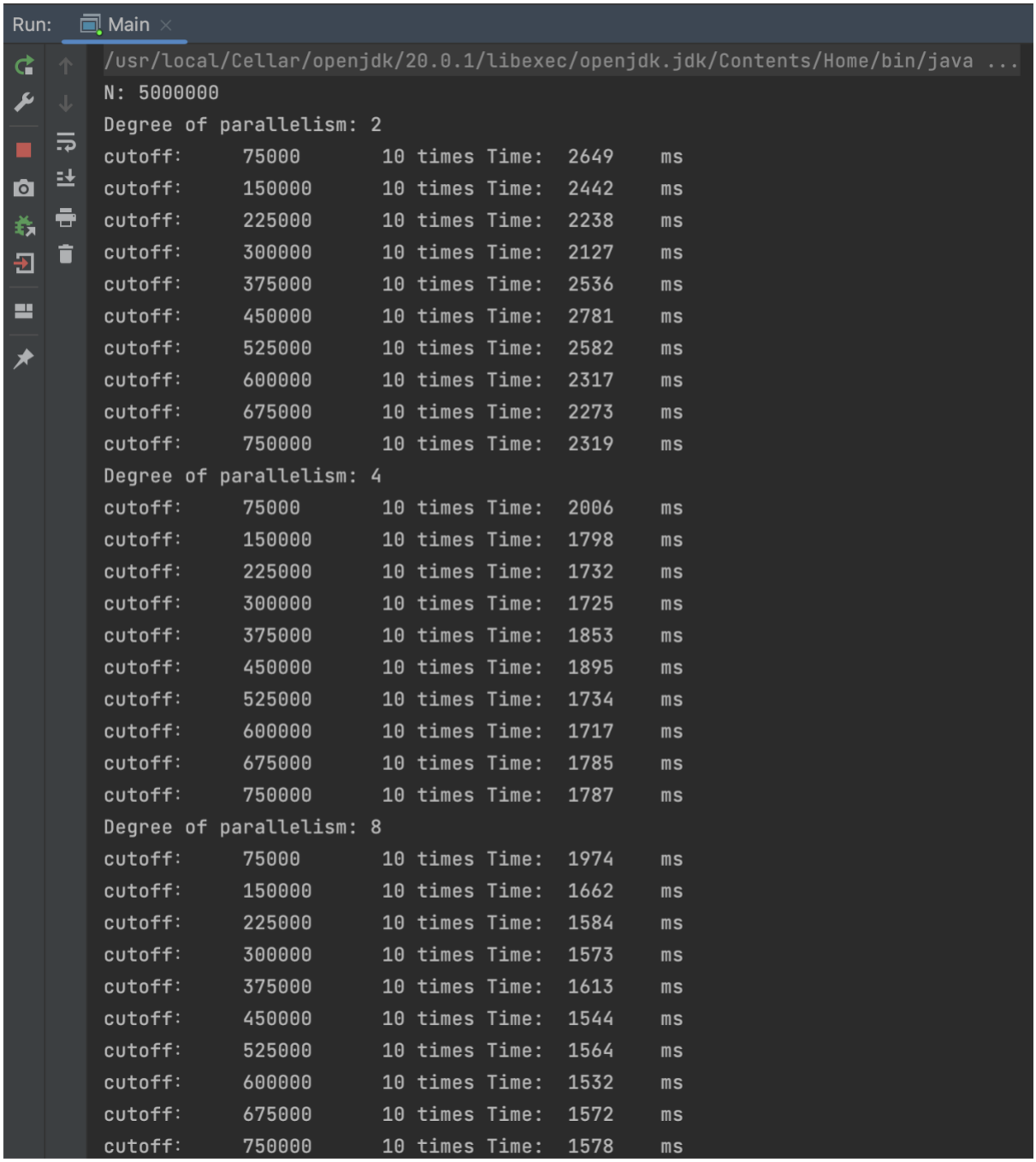
Screenshots of run and/or Unit Test:

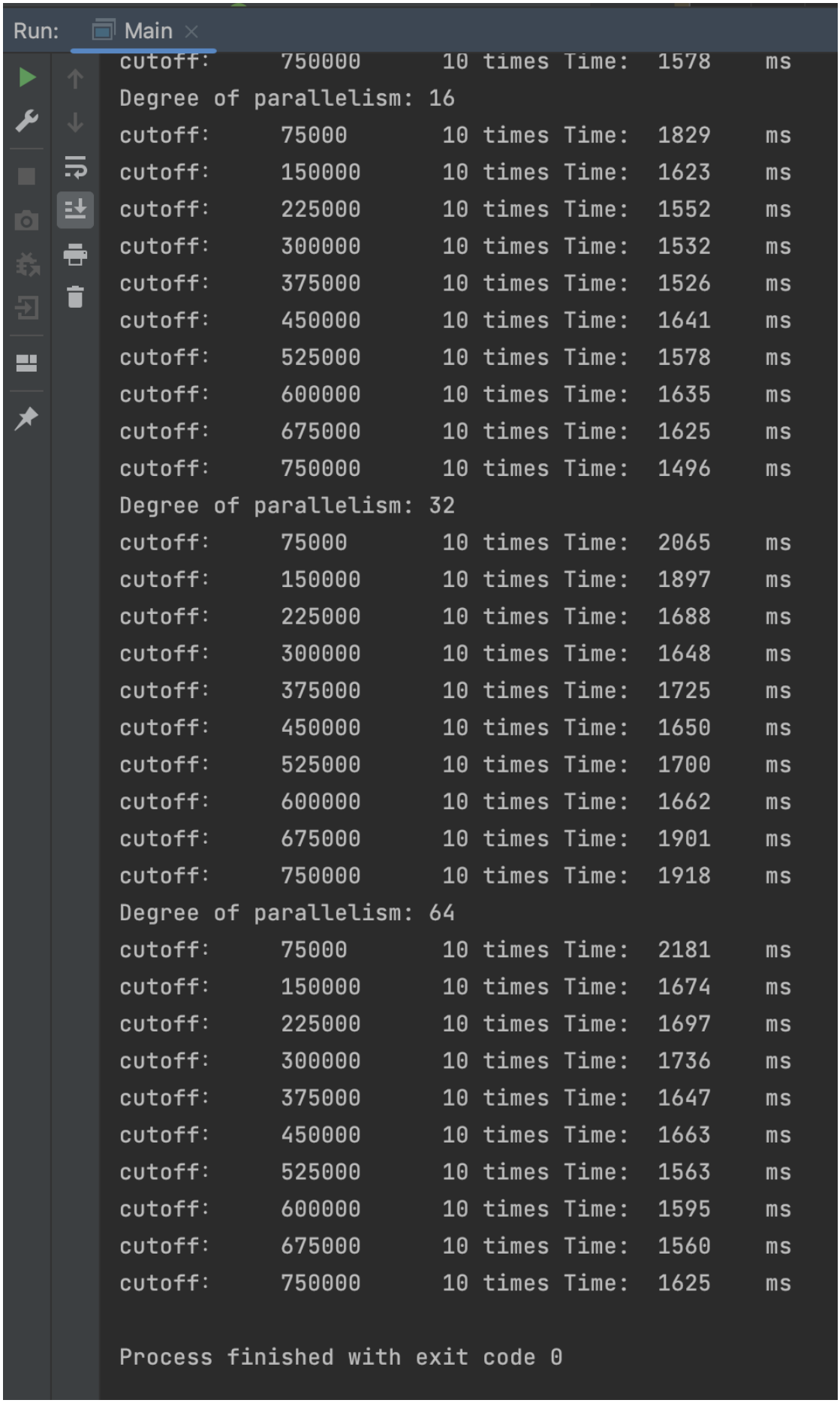



Run:
Main
cutoff: 500000 10 times Time: 307 ms
Degree of parallelism: 16
cutoff: 50000 10 times Time: 363 ms
cutoff: 100000 10 times Time: 287 ms
cutoff: 150000 10 times Time: 278 ms
cutoff: 200000 10 times Time: 269 ms
cutoff: 250000 10 times Time: 275 ms
cutoff: 300000 10 times Time: 309 ms
cutoff: 350000 10 times Time: 319 ms
cutoff: 400000 10 times Time: 324 ms
cutoff: 450000 10 times Time: 324 ms
cutoff: 500000 10 times Time: 330 ms
Degree of parallelism: 32
cutoff: 50000 10 times Time: 303 ms
cutoff: 100000 10 times Time: 284 ms
cutoff: 150000 10 times Time: 318 ms
cutoff: 200000 10 times Time: 318 ms
cutoff: 250000 10 times Time: 351 ms
cutoff: 300000 10 times Time: 365 ms
cutoff: 350000 10 times Time: 323 ms
cutoff: 400000 10 times Time: 316 ms
cutoff: 450000 10 times Time: 315 ms
cutoff: 500000 10 times Time: 314 ms
Degree of parallelism: 64
cutoff: 50000 10 times Time: 288 ms
cutoff: 100000 10 times Time: 297 ms
cutoff: 150000 10 times Time: 329 ms
cutoff: 200000 10 times Time: 322 ms
cutoff: 250000 10 times Time: 318 ms
cutoff: 300000 10 times Time: 366 ms
cutoff: 350000 10 times Time: 345 ms
cutoff: 400000 10 times Time: 342 ms
cutoff: 450000 10 times Time: 362 ms
cutoff: 500000 10 times Time: 336 ms
Process finished with exit code 0


Run:
Main
/usr/local/Cellar/openjdk/20.0.1/libexec/openjdk.jdk/Contents/Home/bin/java ...
N: 2000000
Degree of parallelism: 2
cutoff: 100000 10 times Time: 1265 ms
cutoff: 200000 10 times Time: 811 ms
cutoff: 300000 10 times Time: 818 ms
cutoff: 400000 10 times Time: 912 ms
cutoff: 500000 10 times Time: 990 ms
cutoff: 600000 10 times Time: 916 ms
cutoff: 700000 10 times Time: 979 ms
cutoff: 800000 10 times Time: 972 ms
cutoff: 900000 10 times Time: 940 ms
cutoff: 1000000 10 times Time: 906 ms
Degree of parallelism: 4
cutoff: 100000 10 times Time: 778 ms
cutoff: 200000 10 times Time: 697 ms
cutoff: 300000 10 times Time: 688 ms
cutoff: 400000 10 times Time: 720 ms
cutoff: 500000 10 times Time: 810 ms
cutoff: 600000 10 times Time: 691 ms
cutoff: 700000 10 times Time: 648 ms
cutoff: 800000 10 times Time: 629 ms
cutoff: 900000 10 times Time: 636 ms
cutoff: 1000000 10 times Time: 630 ms
Degree of parallelism: 8
cutoff: 100000 10 times Time: 880 ms
cutoff: 200000 10 times Time: 586 ms
cutoff: 300000 10 times Time: 566 ms
cutoff: 400000 10 times Time: 558 ms
cutoff: 500000 10 times Time: 552 ms
cutoff: 600000 10 times Time: 637 ms
cutoff: 700000 10 times Time: 643 ms
cutoff: 800000 10 times Time: 651 ms
cutoff: 900000 10 times Time: 644 ms
cutoff: 1000000 10 times Time: 638 ms
Degree of parallelism: 16


Run:
Main
cutoff: 1000000 10 times Time: 638 ms
Degree of parallelism: 16
cutoff: 100000 10 times Time: 747 ms
cutoff: 200000 10 times Time: 592 ms
cutoff: 300000 10 times Time: 549 ms
cutoff: 400000 10 times Time: 560 ms
cutoff: 500000 10 times Time: 558 ms
cutoff: 600000 10 times Time: 643 ms
cutoff: 700000 10 times Time: 639 ms
cutoff: 800000 10 times Time: 647 ms
cutoff: 900000 10 times Time: 645 ms
cutoff: 1000000 10 times Time: 660 ms
Degree of parallelism: 32
cutoff: 100000 10 times Time: 629 ms
cutoff: 200000 10 times Time: 563 ms
cutoff: 300000 10 times Time: 563 ms
cutoff: 400000 10 times Time: 554 ms
cutoff: 500000 10 times Time: 559 ms
cutoff: 600000 10 times Time: 640 ms
cutoff: 700000 10 times Time: 638 ms
cutoff: 800000 10 times Time: 641 ms
cutoff: 900000 10 times Time: 654 ms
cutoff: 1000000 10 times Time: 639 ms
Degree of parallelism: 64
cutoff: 100000 10 times Time: 589 ms
cutoff: 200000 10 times Time: 553 ms
cutoff: 300000 10 times Time: 571 ms
cutoff: 400000 10 times Time: 554 ms
cutoff: 500000 10 times Time: 548 ms
cutoff: 600000 10 times Time: 639 ms
cutoff: 700000 10 times Time: 647 ms
cutoff: 800000 10 times Time: 636 ms
cutoff: 900000 10 times Time: 643 ms
cutoff: 1000000 10 times Time: 645 ms
Process finished with exit code 0


Run:
Main
/usr/local/Cellar/openjdk/20.0.1/libexec/openjdk.jdk/Contents/Home/bin/java ...
N: 5000000
Degree of parallelism: 2
cutoff: 75000 10 times Time: 2649 ms
cutoff: 150000 10 times Time: 2442 ms
cutoff: 225000 10 times Time: 2238 ms
cutoff: 300000 10 times Time: 2127 ms
cutoff: 375000 10 times Time: 2536 ms
cutoff: 450000 10 times Time: 2781 ms
cutoff: 525000 10 times Time: 2582 ms
cutoff: 600000 10 times Time: 2317 ms
cutoff: 675000 10 times Time: 2273 ms
cutoff: 750000 10 times Time: 2319 ms
Degree of parallelism: 4
cutoff: 75000 10 times Time: 2006 ms
cutoff: 150000 10 times Time: 1798 ms
cutoff: 225000 10 times Time: 1732 ms
cutoff: 300000 10 times Time: 1725 ms
cutoff: 375000 10 times Time: 1853 ms
cutoff: 450000 10 times Time: 1895 ms
cutoff: 525000 10 times Time: 1734 ms
cutoff: 600000 10 times Time: 1717 ms
cutoff: 675000 10 times Time: 1785 ms
cutoff: 750000 10 times Time: 1787 ms
Degree of parallelism: 8
cutoff: 75000 10 times Time: 1974 ms
cutoff: 150000 10 times Time: 1662 ms
cutoff: 225000 10 times Time: 1584 ms
cutoff: 300000 10 times Time: 1573 ms
cutoff: 375000 10 times Time: 1613 ms
cutoff: 450000 10 times Time: 1544 ms
cutoff: 525000 10 times Time: 1564 ms
cutoff: 600000 10 times Time: 1532 ms
cutoff: 675000 10 times Time: 1572 ms
cutoff: 750000 10 times Time: 1578 ms


Run:
Main
cutoff: 750000 10 times Time: 1578 ms
Degree of parallelism: 16
cutoff: 75000 10 times Time: 1829 ms
cutoff: 150000 10 times Time: 1623 ms
cutoff: 225000 10 times Time: 1552 ms
cutoff: 300000 10 times Time: 1532 ms
cutoff: 375000 10 times Time: 1526 ms
cutoff: 450000 10 times Time: 1641 ms
cutoff: 525000 10 times Time: 1578 ms
cutoff: 600000 10 times Time: 1635 ms
cutoff: 675000 10 times Time: 1625 ms
cutoff: 750000 10 times Time: 1496 ms
Degree of parallelism: 32
cutoff: 75000 10 times Time: 2065 ms
cutoff: 150000 10 times Time: 1897 ms
cutoff: 225000 10 times Time: 1688 ms
cutoff: 300000 10 times Time: 1648 ms
cutoff: 375000 10 times Time: 1725 ms
cutoff: 450000 10 times Time: 1650 ms
cutoff: 525000 10 times Time: 1700 ms
cutoff: 600000 10 times Time: 1662 ms
cutoff: 675000 10 times Time: 1901 ms
cutoff: 750000 10 times Time: 1918 ms
Degree of parallelism: 64
cutoff: 75000 10 times Time: 2181 ms
cutoff: 150000 10 times Time: 1674 ms
cutoff: 225000 10 times Time: 1697 ms
cutoff: 300000 10 times Time: 1736 ms
cutoff: 375000 10 times Time: 1647 ms
cutoff: 450000 10 times Time: 1663 ms
cutoff: 525000 10 times Time: 1563 ms
cutoff: 600000 10 times Time: 1595 ms
cutoff: 675000 10 times Time: 1560 ms
cutoff: 750000 10 times Time: 1625 ms
Process finished with exit code 0