

Program Structures & Algorithms Spring 2023

Assignment No. 5

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:

1. According to the cut-off ratio (cut-off/size of the array), we can see that there is a range of cut-off ratios between 0.3 and 0.55 for which parallel sort can be an ideal option, regardless of the array sizes and the number of threads available for parallel sorting.
2. Analysis of several array sizes (2 million and 16 million) for a range of thread counts (2 to 16) reveals that the best case scenario for 6 threads is achieved.

EVIDENCE TO SUPPORT THE CONCLUSION:

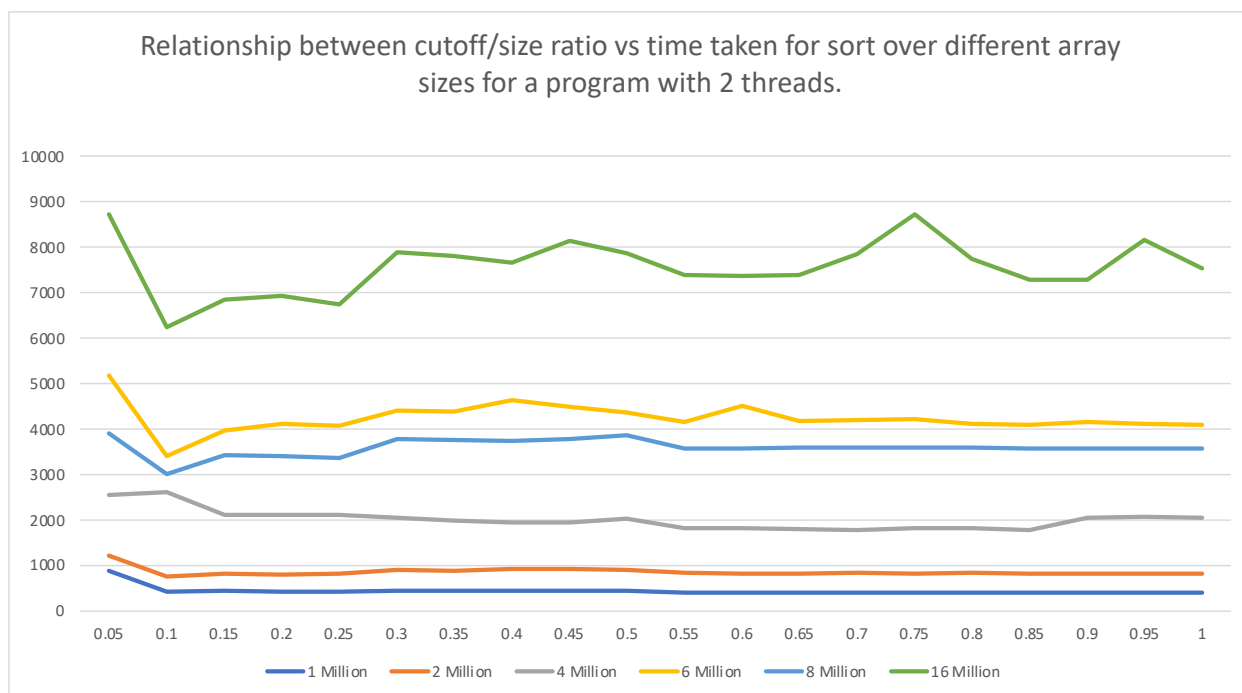
1. Determining the ideal cutoff value for various input array sizes (while keeping the number of threads as a constant).

Threads: 2

Array sizes varied from: 1 million to 6 million, doubling during each run.

Cut-off ratio (Cut-off value/Size of the array): Ranging from 0.05 to 1.0 in increments of 0.05.

cutoff/size	1 Million	2 Million	4 Million	6 Million	8 Million	16 Million
0.05	887	1223	2550	5182	3908	8715
0.1	427	751	2619	3399	3006	6241
0.15	452	824	2123	3979	3418	6845
0.2	431	805	2112	4114	3413	6936
0.25	428	819	2114	4070	3370	6747
0.3	436	895	2048	4412	3781	7887
0.35	442	891	1994	4394	3755	7801
0.4	440	935	1952	4647	3741	7669
0.45	437	935	1956	4499	3783	8133
0.5	436	914	2033	4369	3855	7864
0.55	402	834	1817	4161	3570	7384
0.6	402	826	1815	4503	3574	7378
0.65	402	827	1806	4175	3590	7393
0.7	403	832	1778	4193	3586	7855
0.75	401	823	1831	4220	3587	8721
0.8	403	832	1824	4118	3593	7744
0.85	400	828	1771	4100	3571	7293
0.9	403	823	2055	4151	3572	7286
0.95	403	822	2075	4110	3569	8152
1	402	822	2042	4089	3577	7544

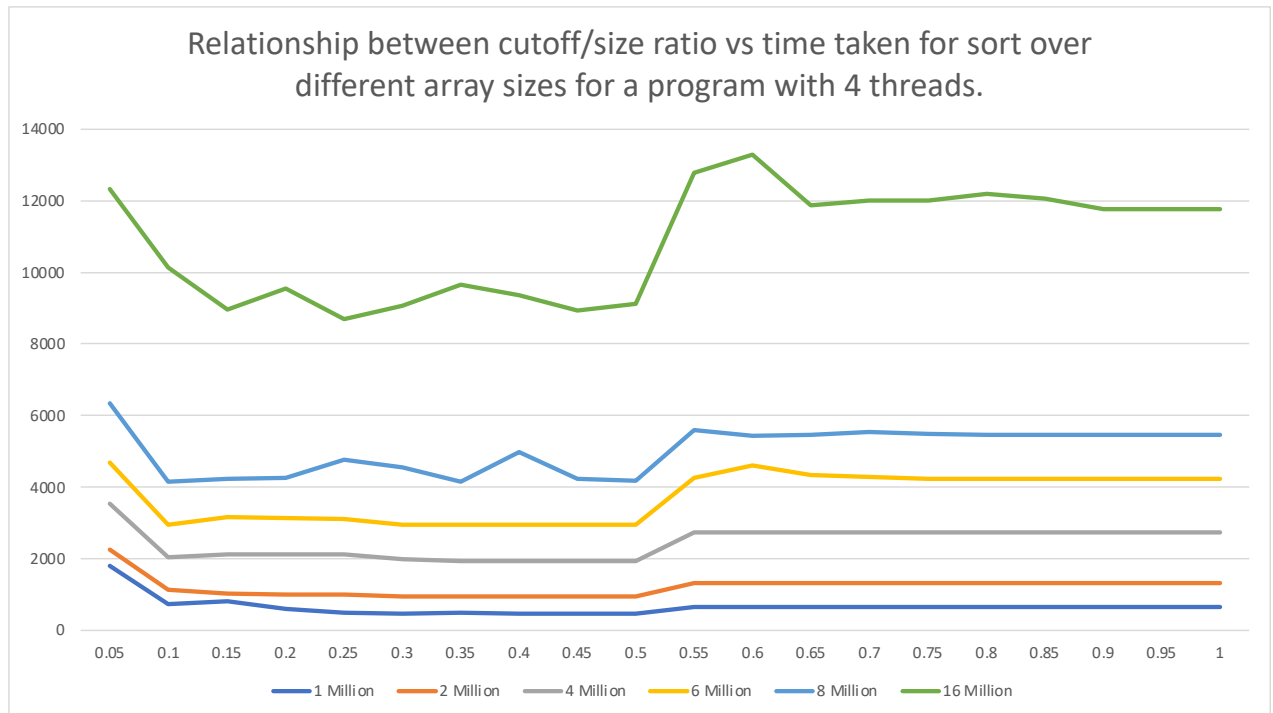


Threads: 4

Array sizes varied from: 1 million to 6 million, doubling during each run.

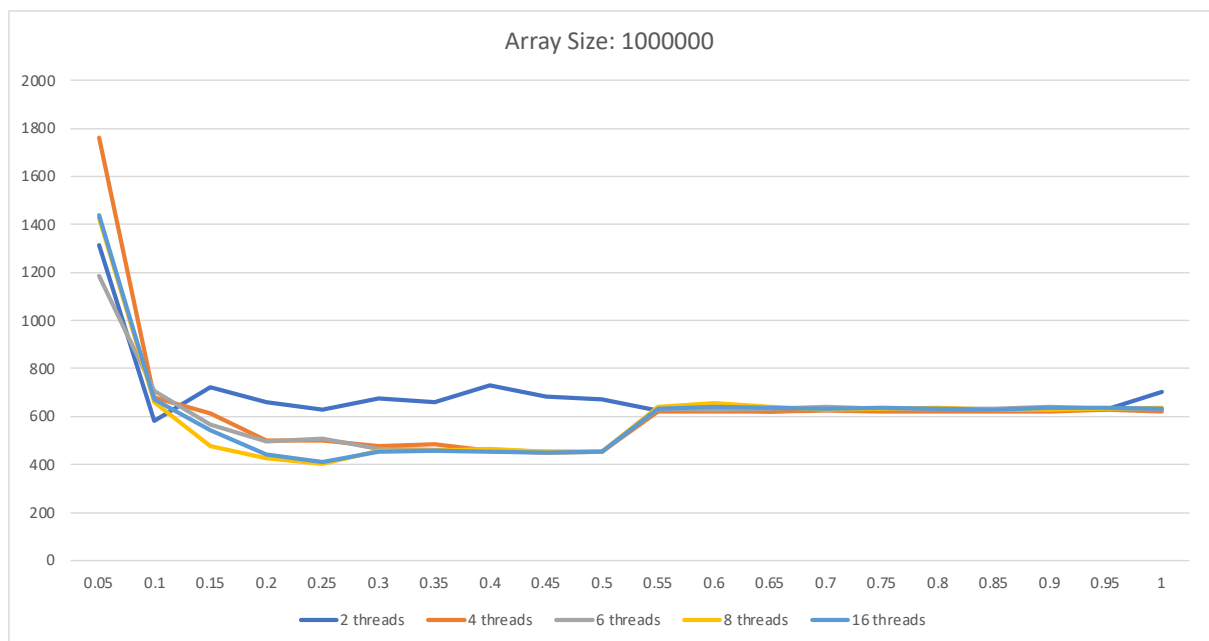
Cut-off ratio (Cut-off value/Size of the array): Ranging from 0.05 to 1.0 in increments of 0.05.

cutoff/size	1 Million	2 Million	4 Million	6 Million	8 Million	16 Million
0.05	1802	2259	3531	4689	6354	12324
0.1	741	1130	2036	2945	4144	10134
0.15	817	1023	2127	3173	4243	8962
0.2	589	1006	2134	3126	4270	9535
0.25	498	999	2121	3106	4758	8694
0.3	469	937	1990	2942	4540	9057
0.35	488	939	1939	2942	4146	9663
0.4	469	938	1944	2943	4980	9369
0.45	463	938	1946	2943	4224	8936
0.5	461	935	1943	2936	4183	9112
0.55	644	1318	2737	4260	5596	12783
0.6	643	1320	2736	4609	5444	13297
0.65	641	1324	2737	4343	5453	11872
0.7	648	1317	2746	4291	5542	11993
0.75	650	1320	2735	4242	5480	12008
0.8	648	1315	2733	4236	5453	12191
0.85	640	1315	2743	4236	5461	12068
0.9	639	1310	2732	4236	5464	11775
0.95	641	1313	2729	4231	5452	11757
1	641	1314	2729	4243	5450	11754



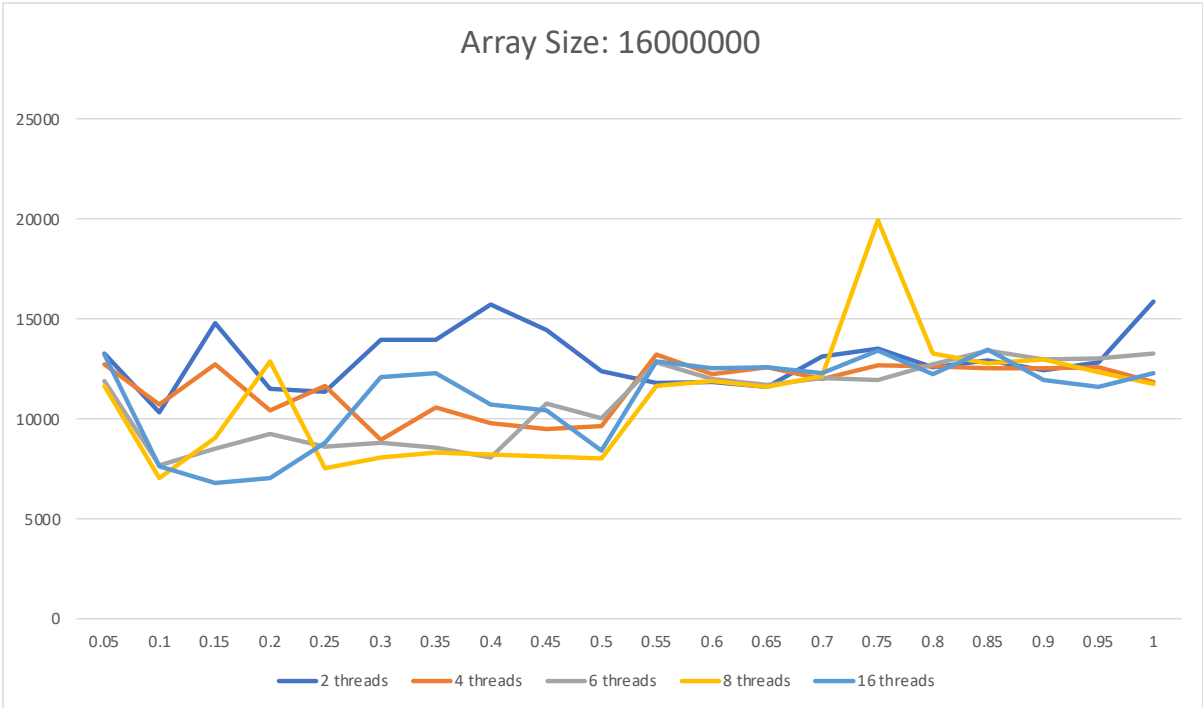
2. Checking for different threads from 2 to 16 for an array of 1000000 elements, with cutoff ratios changing from 0.05 to 1.0

cutoff/size	2 threads	4 threads	6 threads	8 threads	16 threads
0.05	1313	1761	1186	1426	1439
0.1	583	680	707	659	673
0.15	721	614	565	478	542
0.2	658	500	497	424	442
0.25	627	501	507	404	409
0.3	674	475	464	456	453
0.35	661	485	459	457	456
0.4	729	458	459	464	455
0.45	682	451	452	453	450
0.5	670	453	454	452	455
0.55	623	620	633	639	633
0.6	630	620	630	654	639
0.65	622	619	633	641	635
0.7	627	623	640	629	633
0.75	623	620	631	632	636
0.8	629	621	632	635	631
0.85	623	621	632	629	630
0.9	628	621	639	630	635
0.95	628	627	632	633	636
1	701	620	632	636	633

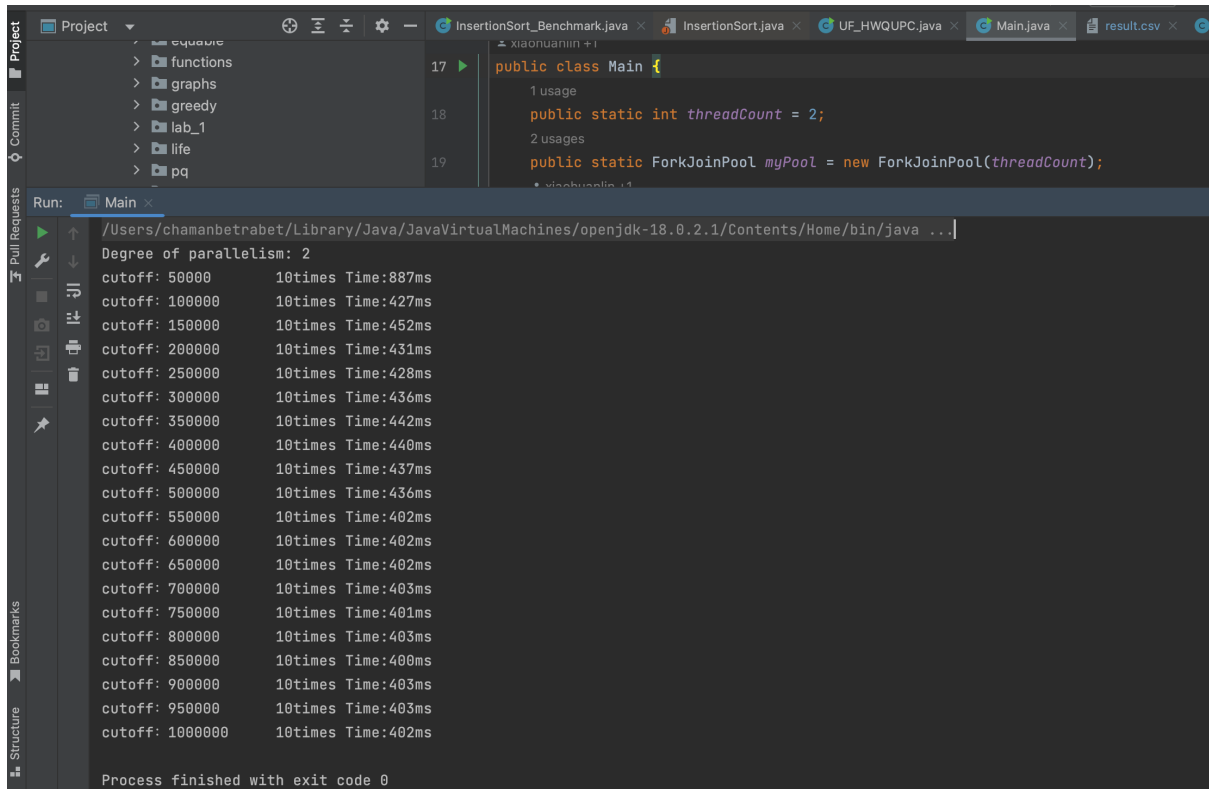


Checking for different threads from 2 to 16 for an array of 16000000 elements, with cutoff ratios changing from 0.05 to 1.0

cutoff/size	2 threads	4 threads	6 threads	8 threads	16 threads
0.05	13258	12724	11883	11645	13221
0.1	10301	10697	7681	7053	7639
0.15	14787	12718	8511	9040	6785
0.2	11492	10396	9220	12881	7041
0.25	11323	11663	8625	7515	8787
0.3	13958	8939	8783	8080	12075
0.35	13963	10564	8569	8299	12274
0.4	15723	9778	8047	8190	10707
0.45	14455	9490	10777	8121	10410
0.5	12373	9627	10033	7989	8415
0.55	11795	13231	12839	11648	12854
0.6	11827	12241	12004	11873	12501
0.65	11602	12594	11702	11568	12565
0.7	13092	11970	12043	12146	12266
0.75	13491	12661	11945	19930	13431
0.8	12576	12637	12702	13250	12215
0.85	12926	12502	13402	12749	13434
0.9	12413	12505	12957	12958	11912
0.95	12811	12556	13035	12348	11583
1	15837	11841	13251	11752	12299



Output for conclusion 1:



The screenshot shows an IDE with a project structure on the left, a code editor in the center, and a run console at the bottom. The project structure includes folders like 'equable', 'functions', 'graphs', 'greedy', 'lab_1', 'life', and 'pq'. The code editor displays the 'Main.java' file with the following code:

```
17 public class Main {  
18     1 usage  
19     public static int threadCount = 2;  
20     2 usages  
21     public static ForkJoinPool myPool = new ForkJoinPool(threadCount);  
22 }
```

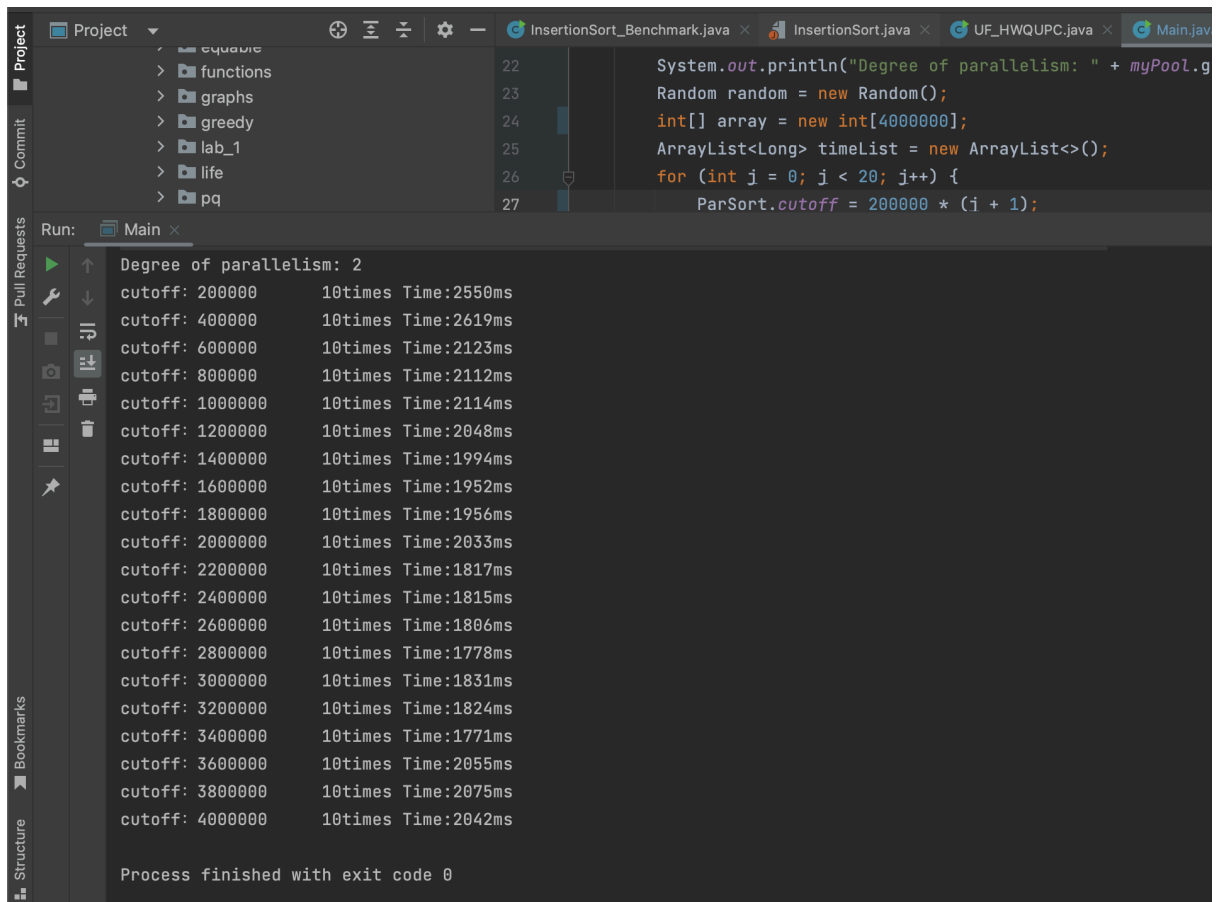
The run console shows the output of the program, which is a benchmark for insertion sort. The output is as follows:

```
Run: Main  
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...  
Degree of parallelism: 2  
cutoff: 500000 10times Time:887ms  
cutoff: 100000 10times Time:427ms  
cutoff: 150000 10times Time:452ms  
cutoff: 200000 10times Time:431ms  
cutoff: 250000 10times Time:428ms  
cutoff: 300000 10times Time:436ms  
cutoff: 350000 10times Time:442ms  
cutoff: 400000 10times Time:440ms  
cutoff: 450000 10times Time:437ms  
cutoff: 500000 10times Time:436ms  
cutoff: 550000 10times Time:402ms  
cutoff: 600000 10times Time:402ms  
cutoff: 650000 10times Time:402ms  
cutoff: 700000 10times Time:403ms  
cutoff: 750000 10times Time:401ms  
cutoff: 800000 10times Time:403ms  
cutoff: 850000 10times Time:400ms  
cutoff: 900000 10times Time:403ms  
cutoff: 950000 10times Time:403ms  
cutoff: 1000000 10times Time:402ms  
Process finished with exit code 0
```



```
INFO6205 > src > main > java > edu > neu > coe > info6205 > sort > par > Main > main
Project
  > equable
  > functions
  > graphs
  > greedy
  > ...
Commit
Run: Main x
  /Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java .
Degree of parallelism: 2
cutoff: 100000      10times Time:1223ms
cutoff: 200000      10times Time:751ms
cutoff: 300000      10times Time:824ms
cutoff: 400000      10times Time:805ms
cutoff: 500000      10times Time:819ms
cutoff: 600000      10times Time:895ms
cutoff: 700000      10times Time:891ms
cutoff: 800000      10times Time:935ms
cutoff: 900000      10times Time:935ms
cutoff: 1000000     10times Time:914ms
cutoff: 1100000     10times Time:834ms
cutoff: 1200000     10times Time:826ms
cutoff: 1300000     10times Time:827ms
cutoff: 1400000     10times Time:832ms
cutoff: 1500000     10times Time:823ms
cutoff: 1600000     10times Time:832ms
cutoff: 1700000     10times Time:828ms
cutoff: 1800000     10times Time:823ms
cutoff: 1900000     10times Time:822ms
cutoff: 2000000     10times Time:822ms

Process finished with exit code 0
```



The screenshot shows an IDE with a project named 'equable' containing subfolders 'functions', 'graphs', and 'greedy'. The file 'InsertionSort_Benchmark.java' is open, showing a loop starting at line 26. The console output shows the execution of a benchmark with a degree of parallelism of 2, testing various cutoff values from 300,000 to 6,000,000. Each test runs 10 times, and the time taken is recorded in milliseconds. The process finished with exit code 0.

```
Project ▾
  equable
    functions
    graphs
    greedy

InsertionSort_Benchmark.java x
26
27
28

for (int j =
ParSort.
// for (

Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18
Degree of parallelism: 2
cutoff: 300000      10times Time:5182ms
cutoff: 600000      10times Time:3399ms
cutoff: 900000      10times Time:3979ms
cutoff: 1200000     10times Time:4114ms
cutoff: 1500000     10times Time:4070ms
cutoff: 1800000     10times Time:4412ms
cutoff: 2100000     10times Time:4394ms
cutoff: 2400000     10times Time:4647ms
cutoff: 2700000     10times Time:4499ms
cutoff: 3000000     10times Time:4369ms
cutoff: 3300000     10times Time:4161ms
cutoff: 3600000     10times Time:4503ms
cutoff: 3900000     10times Time:4175ms
cutoff: 4200000     10times Time:4193ms
cutoff: 4500000     10times Time:4220ms
cutoff: 4800000     10times Time:4118ms
cutoff: 5100000     10times Time:4100ms
cutoff: 5400000     10times Time:4151ms
cutoff: 5700000     10times Time:4110ms
cutoff: 6000000     10times Time:4089ms

Process finished with exit code 0
```

```
Project
  > functions
  > graphs
  > greedy
  > lab_1
  > life
  > ...

Run: Main
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 2
cutoff: 400000      10times Time:3908ms
cutoff: 800000      10times Time:3006ms
cutoff: 1200000     10times Time:3418ms
cutoff: 1600000     10times Time:3413ms
cutoff: 2000000     10times Time:3370ms
cutoff: 2400000     10times Time:3781ms
cutoff: 2800000     10times Time:3755ms
cutoff: 3200000     10times Time:3741ms
cutoff: 3600000     10times Time:3783ms
cutoff: 4000000     10times Time:3855ms
cutoff: 4400000     10times Time:3570ms
cutoff: 4800000     10times Time:3574ms
cutoff: 5200000     10times Time:3590ms
cutoff: 5600000     10times Time:3586ms
cutoff: 6000000     10times Time:3587ms
cutoff: 6400000     10times Time:3593ms
cutoff: 6800000     10times Time:3571ms
cutoff: 7200000     10times Time:3572ms
cutoff: 7600000     10times Time:3569ms
cutoff: 8000000     10times Time:3577ms

Process finished with exit code 0
```

```
Project
  > functions
  > graphs
  > greedy
  > lab_1
  > life
  > ...

Run: Main
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 4
cutoff: 50000      10times Time:1802ms
cutoff: 100000     10times Time:741ms
cutoff: 150000     10times Time:817ms
cutoff: 200000     10times Time:589ms
cutoff: 250000     10times Time:498ms
cutoff: 300000     10times Time:469ms
cutoff: 350000     10times Time:488ms
cutoff: 400000     10times Time:469ms
cutoff: 450000     10times Time:463ms
cutoff: 500000     10times Time:461ms
cutoff: 550000     10times Time:644ms
cutoff: 600000     10times Time:643ms
cutoff: 650000     10times Time:641ms
cutoff: 700000     10times Time:648ms
cutoff: 750000     10times Time:650ms
cutoff: 800000     10times Time:648ms
cutoff: 850000     10times Time:640ms
cutoff: 900000     10times Time:639ms
cutoff: 950000     10times Time:641ms
cutoff: 1000000    10times Time:641ms

Process finished with exit code 0
```

```
INFO6205 > src > main > java > edu > neu > coe > info6205 > sort > par > Main > main

Project
  equable
  functions
  graphs
  greedy

InsertionSort_Benchmark.java
InsertionSort.java
UF_HWQUPC.java

Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java
Degree of parallelism: 2
cutoff: 800000      10times Time:8715ms
cutoff: 1600000    10times Time:6241ms
cutoff: 2400000    10times Time:6845ms
cutoff: 3200000    10times Time:6936ms
cutoff: 4000000    10times Time:6747ms
cutoff: 4800000    10times Time:7887ms
cutoff: 5600000    10times Time:7801ms
cutoff: 6400000    10times Time:7669ms
cutoff: 7200000    10times Time:8133ms
cutoff: 8000000    10times Time:7864ms
cutoff: 8800000    10times Time:7384ms
cutoff: 9600000    10times Time:7378ms
cutoff: 10400000   10times Time:7393ms
cutoff: 11200000   10times Time:7855ms
cutoff: 12000000   10times Time:8721ms
cutoff: 12800000   10times Time:7744ms
cutoff: 13600000   10times Time:7293ms
cutoff: 14400000   10times Time:7286ms
cutoff: 15200000   10times Time:8152ms
cutoff: 16000000   10times Time:7544ms

Process finished with exit code 0
```

```
Project
  equable
  functions
  graphs
  greedy
  lab_1
  life
  na

InsertionSort_Benchmark.java
InsertionSort.java

Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java
Degree of parallelism: 4
cutoff: 50000      10times Time:1802ms
cutoff: 100000     10times Time:741ms
cutoff: 150000     10times Time:817ms
cutoff: 200000     10times Time:589ms
cutoff: 250000     10times Time:498ms
cutoff: 300000     10times Time:469ms
cutoff: 350000     10times Time:488ms
cutoff: 400000     10times Time:469ms
cutoff: 450000     10times Time:463ms
cutoff: 500000     10times Time:461ms
cutoff: 550000     10times Time:644ms
cutoff: 600000     10times Time:643ms
cutoff: 650000     10times Time:641ms
cutoff: 700000     10times Time:648ms
cutoff: 750000     10times Time:650ms
cutoff: 800000     10times Time:648ms
cutoff: 850000     10times Time:640ms
cutoff: 900000     10times Time:639ms
cutoff: 950000     10times Time:641ms
cutoff: 1000000    10times Time:641ms

Process finished with exit code 0
```

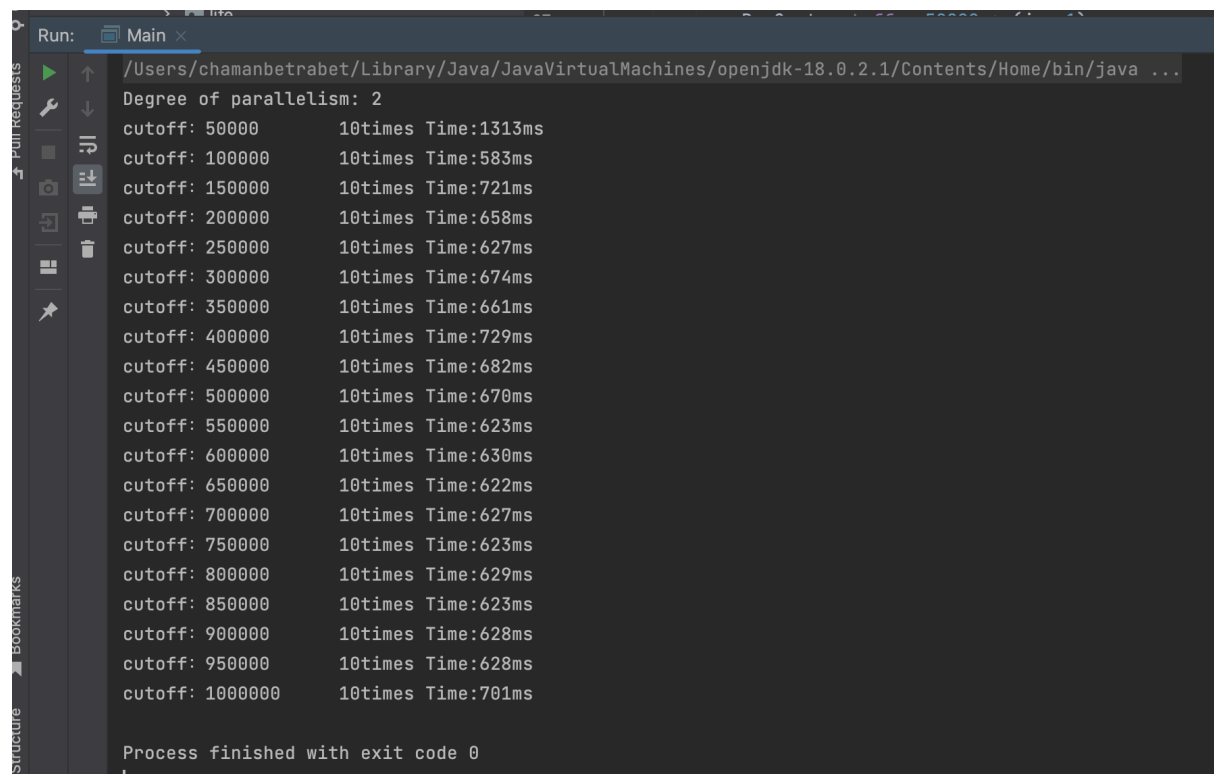
```
INFO6205 > src > main > java > edu > neu > coe > info6205 > sort > par > Main > main
Project: square, functions, graphs, greedy, lab_1, life
Commit:
Pull Requests:
Structure:
Run: Main
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 4
cutoff: 200000      10times Time:3531ms
cutoff: 400000      10times Time:2036ms
cutoff: 600000      10times Time:2127ms
cutoff: 800000      10times Time:2134ms
cutoff: 1000000     10times Time:2121ms
cutoff: 1200000     10times Time:1990ms
cutoff: 1400000     10times Time:1939ms
cutoff: 1600000     10times Time:1944ms
cutoff: 1800000     10times Time:1946ms
cutoff: 2000000     10times Time:1943ms
cutoff: 2200000     10times Time:2737ms
cutoff: 2400000     10times Time:2736ms
cutoff: 2600000     10times Time:2737ms
cutoff: 2800000     10times Time:2746ms
cutoff: 3000000     10times Time:2735ms
cutoff: 3200000     10times Time:2733ms
cutoff: 3400000     10times Time:2743ms
cutoff: 3600000     10times Time:2732ms
cutoff: 3800000     10times Time:2729ms
cutoff: 4000000     10times Time:2729ms
Process finished with exit code 0
```

```
INFO6205 > src > main > java > edu > neu > coe > info6205 > sort > par > Main > main
Project: square, functions, graphs, greedy, lab_1, life
Commit:
Pull Requests:
Structure:
Run: Main
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 4
cutoff: 300000      10times Time:4689ms
cutoff: 600000      10times Time:2945ms
cutoff: 900000      10times Time:3173ms
cutoff: 1200000     10times Time:3126ms
cutoff: 1500000     10times Time:3106ms
cutoff: 1800000     10times Time:2942ms
cutoff: 2100000     10times Time:2942ms
cutoff: 2400000     10times Time:2943ms
cutoff: 2700000     10times Time:2943ms
cutoff: 3000000     10times Time:2936ms
cutoff: 3300000     10times Time:4260ms
cutoff: 3600000     10times Time:4609ms
cutoff: 3900000     10times Time:4343ms
cutoff: 4200000     10times Time:4291ms
cutoff: 4500000     10times Time:4242ms
cutoff: 4800000     10times Time:4236ms
cutoff: 5100000     10times Time:4236ms
cutoff: 5400000     10times Time:4236ms
cutoff: 5700000     10times Time:4231ms
cutoff: 6000000     10times Time:4243ms
Process finished with exit code 0
```

```
INFO6205 > src > main > java > edu > neu > coe > info6205 > sort > par > Main > main
Project
  equable
  functions
  25
  ArrayList<
InsertionSort_Benchmark.java x
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-1
Degree of parallelism: 4
cutoff: 800000      10times Time:12324ms
cutoff: 1600000    10times Time:10134ms
cutoff: 2400000    10times Time:8962ms
cutoff: 3200000    10times Time:9535ms
cutoff: 4000000    10times Time:8694ms
cutoff: 4800000    10times Time:9057ms
cutoff: 5600000    10times Time:9663ms
cutoff: 6400000    10times Time:9369ms
cutoff: 7200000    10times Time:8936ms
cutoff: 8000000    10times Time:9112ms
cutoff: 8800000    10times Time:12783ms
cutoff: 9600000    10times Time:13297ms
cutoff: 10400000   10times Time:11872ms
cutoff: 11200000   10times Time:11993ms
cutoff: 12000000   10times Time:12008ms
cutoff: 12800000   10times Time:12191ms
cutoff: 13600000   10times Time:12068ms
cutoff: 14400000   10times Time:11775ms
cutoff: 15200000   10times Time:11757ms
cutoff: 16000000   10times Time:11754ms

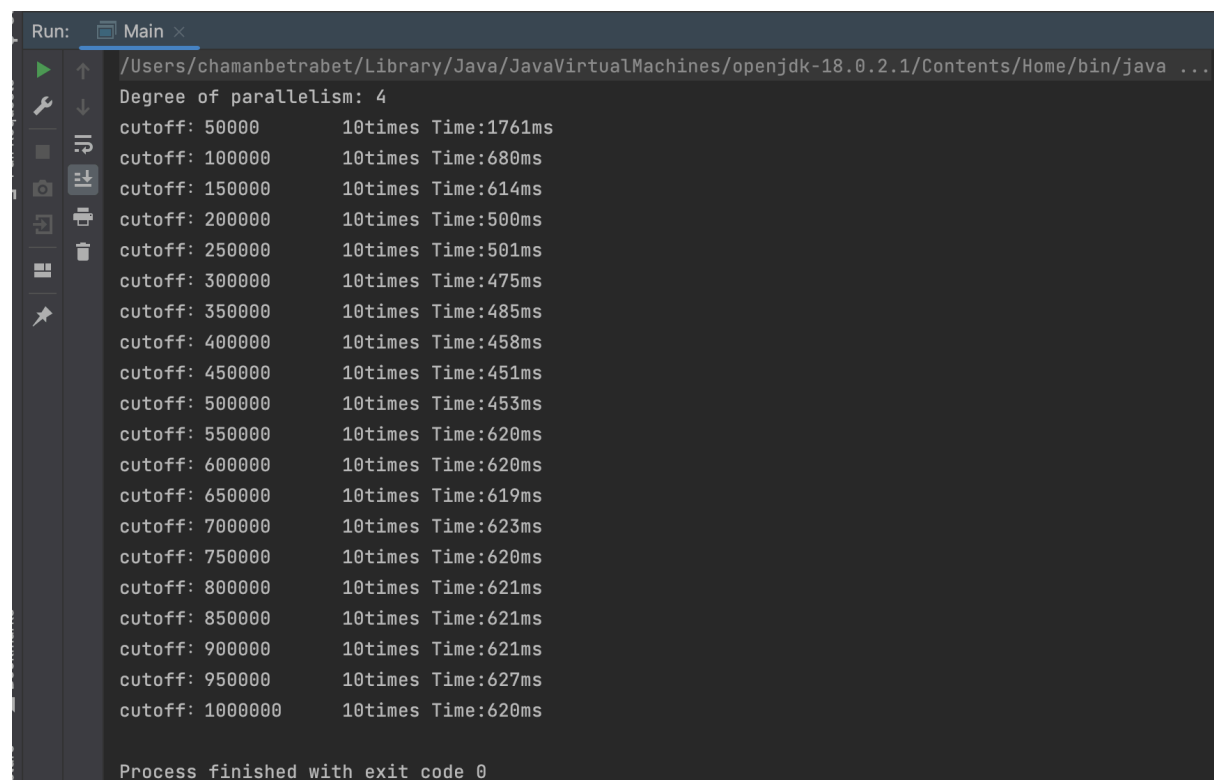
Process finished with exit code 0
|
```

Output screenshots for conclusion 2:



```
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 2
cutoff: 50000      10times Time:1313ms
cutoff: 100000    10times Time:583ms
cutoff: 150000    10times Time:721ms
cutoff: 200000    10times Time:658ms
cutoff: 250000    10times Time:627ms
cutoff: 300000    10times Time:674ms
cutoff: 350000    10times Time:661ms
cutoff: 400000    10times Time:729ms
cutoff: 450000    10times Time:682ms
cutoff: 500000    10times Time:670ms
cutoff: 550000    10times Time:623ms
cutoff: 600000    10times Time:630ms
cutoff: 650000    10times Time:622ms
cutoff: 700000    10times Time:627ms
cutoff: 750000    10times Time:623ms
cutoff: 800000    10times Time:629ms
cutoff: 850000    10times Time:623ms
cutoff: 900000    10times Time:628ms
cutoff: 950000    10times Time:628ms
cutoff: 1000000   10times Time:701ms

Process finished with exit code 0
```



```
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 4
cutoff: 50000      10times Time:1761ms
cutoff: 100000    10times Time:680ms
cutoff: 150000    10times Time:614ms
cutoff: 200000    10times Time:500ms
cutoff: 250000    10times Time:501ms
cutoff: 300000    10times Time:475ms
cutoff: 350000    10times Time:485ms
cutoff: 400000    10times Time:458ms
cutoff: 450000    10times Time:451ms
cutoff: 500000    10times Time:453ms
cutoff: 550000    10times Time:620ms
cutoff: 600000    10times Time:620ms
cutoff: 650000    10times Time:619ms
cutoff: 700000    10times Time:623ms
cutoff: 750000    10times Time:620ms
cutoff: 800000    10times Time:621ms
cutoff: 850000    10times Time:621ms
cutoff: 900000    10times Time:621ms
cutoff: 950000    10times Time:627ms
cutoff: 1000000   10times Time:620ms

Process finished with exit code 0
```



```
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 6
cutoff: 50000      10times Time:1186ms
cutoff: 100000     10times Time:707ms
cutoff: 150000     10times Time:565ms
cutoff: 200000     10times Time:497ms
cutoff: 250000     10times Time:507ms
cutoff: 300000     10times Time:464ms
cutoff: 350000     10times Time:459ms
cutoff: 400000     10times Time:459ms
cutoff: 450000     10times Time:452ms
cutoff: 500000     10times Time:454ms
cutoff: 550000     10times Time:633ms
cutoff: 600000     10times Time:630ms
cutoff: 650000     10times Time:633ms
cutoff: 700000     10times Time:640ms
cutoff: 750000     10times Time:631ms
cutoff: 800000     10times Time:632ms
cutoff: 850000     10times Time:632ms
cutoff: 900000     10times Time:639ms
cutoff: 950000     10times Time:632ms
cutoff: 1000000    10times Time:632ms

Process finished with exit code 0
```

```
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 8
cutoff: 50000      10times Time:1426ms
cutoff: 100000     10times Time:659ms
cutoff: 150000     10times Time:478ms
cutoff: 200000     10times Time:424ms
cutoff: 250000     10times Time:404ms
cutoff: 300000     10times Time:456ms
cutoff: 350000     10times Time:457ms
cutoff: 400000     10times Time:464ms
cutoff: 450000     10times Time:453ms
cutoff: 500000     10times Time:452ms
cutoff: 550000     10times Time:639ms
cutoff: 600000     10times Time:654ms
cutoff: 650000     10times Time:641ms
cutoff: 700000     10times Time:629ms
cutoff: 750000     10times Time:632ms
cutoff: 800000     10times Time:635ms
cutoff: 850000     10times Time:629ms
cutoff: 900000     10times Time:630ms
cutoff: 950000     10times Time:633ms
cutoff: 1000000    10times Time:636ms

Process finished with exit code 0
```

```
Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 16
cutoff: 500000      10times Time:1439ms
cutoff: 1000000    10times Time:673ms
cutoff: 1500000    10times Time:542ms
cutoff: 2000000    10times Time:442ms
cutoff: 2500000    10times Time:409ms
cutoff: 3000000    10times Time:453ms
cutoff: 3500000    10times Time:456ms
cutoff: 4000000    10times Time:455ms
cutoff: 4500000    10times Time:450ms
cutoff: 5000000    10times Time:455ms
cutoff: 5500000    10times Time:633ms
cutoff: 6000000    10times Time:639ms
cutoff: 6500000    10times Time:635ms
cutoff: 7000000    10times Time:633ms
cutoff: 7500000    10times Time:636ms
cutoff: 8000000    10times Time:631ms
cutoff: 8500000    10times Time:630ms
cutoff: 9000000    10times Time:635ms
cutoff: 9500000    10times Time:636ms
cutoff: 10000000   10times Time:633ms

Process finished with exit code 0
```

```
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 2
cutoff: 800000      10times Time:13258ms
cutoff: 1600000    10times Time:10301ms
cutoff: 2400000    10times Time:14787ms
cutoff: 3200000    10times Time:11492ms
cutoff: 4000000    10times Time:11323ms
cutoff: 4800000    10times Time:13958ms
cutoff: 5600000    10times Time:13963ms
cutoff: 6400000    10times Time:15723ms
cutoff: 7200000    10times Time:14455ms
cutoff: 8000000    10times Time:12373ms
cutoff: 8800000    10times Time:11795ms
cutoff: 9600000    10times Time:11827ms
cutoff: 10400000   10times Time:11602ms
cutoff: 11200000   10times Time:13092ms
cutoff: 12000000   10times Time:13491ms
cutoff: 12800000   10times Time:12576ms
cutoff: 13600000   10times Time:12926ms
cutoff: 14400000   10times Time:12413ms
cutoff: 15200000   10times Time:12811ms
cutoff: 16000000   10times Time:15837ms

Process finished with exit code 0
```

```
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 4
cutoff: 800000      10times Time:12724ms
cutoff: 1600000     10times Time:10697ms
cutoff: 2400000     10times Time:12718ms
cutoff: 3200000     10times Time:10396ms
cutoff: 4000000     10times Time:11663ms
cutoff: 4800000     10times Time:8939ms
cutoff: 5600000     10times Time:10564ms
cutoff: 6400000     10times Time:9778ms
cutoff: 7200000     10times Time:9490ms
cutoff: 8000000     10times Time:9627ms
cutoff: 8800000     10times Time:13231ms
cutoff: 9600000     10times Time:12241ms
cutoff: 10400000    10times Time:12594ms
cutoff: 11200000    10times Time:11970ms
cutoff: 12000000    10times Time:12661ms
cutoff: 12800000    10times Time:12637ms
cutoff: 13600000    10times Time:12502ms
cutoff: 14400000    10times Time:12505ms
cutoff: 15200000    10times Time:12556ms
cutoff: 16000000    10times Time:11841ms

Process finished with exit code 0
```

```
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 6
cutoff: 800000      10times Time:11883ms
cutoff: 1600000     10times Time:7681ms
cutoff: 2400000     10times Time:8511ms
cutoff: 3200000     10times Time:9220ms
cutoff: 4000000     10times Time:8625ms
cutoff: 4800000     10times Time:8783ms
cutoff: 5600000     10times Time:8569ms
cutoff: 6400000     10times Time:8047ms
cutoff: 7200000     10times Time:10777ms
cutoff: 8000000     10times Time:10033ms
cutoff: 8800000     10times Time:12839ms
cutoff: 9600000     10times Time:12004ms
cutoff: 10400000    10times Time:11702ms
cutoff: 11200000    10times Time:12043ms
cutoff: 12000000    10times Time:11945ms
cutoff: 12800000    10times Time:12702ms
cutoff: 13600000    10times Time:13402ms
cutoff: 14400000    10times Time:12957ms
cutoff: 15200000    10times Time:13035ms
cutoff: 16000000    10times Time:13251ms

Process finished with exit code 0
```

```
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 8
cutoff: 800000      10times Time:11645ms
cutoff: 1600000    10times Time:7053ms
cutoff: 2400000    10times Time:9040ms
cutoff: 3200000    10times Time:12881ms
cutoff: 4000000    10times Time:7515ms
cutoff: 4800000    10times Time:8080ms
cutoff: 5600000    10times Time:8299ms
cutoff: 6400000    10times Time:8190ms
cutoff: 7200000    10times Time:8121ms
cutoff: 8000000    10times Time:7989ms
cutoff: 8800000    10times Time:11648ms
cutoff: 9600000    10times Time:11873ms
cutoff: 10400000   10times Time:11568ms
cutoff: 11200000   10times Time:12146ms
cutoff: 12000000   10times Time:19930ms
cutoff: 12800000   10times Time:13250ms
cutoff: 13600000   10times Time:12749ms
cutoff: 14400000   10times Time:12958ms
cutoff: 15200000   10times Time:12348ms
cutoff: 16000000   10times Time:11752ms

Process finished with exit code 0
```

```
Run: Main x
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Degree of parallelism: 16
cutoff: 800000      10times Time:13221ms
cutoff: 1600000    10times Time:7639ms
cutoff: 2400000    10times Time:6785ms
cutoff: 3200000    10times Time:7041ms
cutoff: 4000000    10times Time:8787ms
cutoff: 4800000    10times Time:12075ms
cutoff: 5600000    10times Time:12274ms
cutoff: 6400000    10times Time:10707ms
cutoff: 7200000    10times Time:10410ms
cutoff: 8000000    10times Time:8415ms
cutoff: 8800000    10times Time:12854ms
cutoff: 9600000    10times Time:12501ms
cutoff: 10400000   10times Time:12565ms
cutoff: 11200000   10times Time:12266ms
cutoff: 12000000   10times Time:13431ms
cutoff: 12800000   10times Time:12215ms
cutoff: 13600000   10times Time:13434ms
cutoff: 14400000   10times Time:11912ms
cutoff: 15200000   10times Time:11583ms
cutoff: 16000000   10times Time:12299ms

Process finished with exit code 0
```