Program Structures & Algorithms
Spring 2022
Assignment No. 4

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Task

- 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.

- (Part 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.

- (Part 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).

- (Part 3) Implement a main program to run the following benchmarks: measure the running times of this sort.

- Show the results of your experiments and draws a conclusion (or more) about the efficacy of this method of parallelizing sort.

- 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

We have run simulations of experiments with different combinations of the cutoff values, threads and array sizes. From the observations of the runtimes, we can conclude that four threads is the optimal choice and there wouldn’t be much improvement in algorithm performance beyond four threads.

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

For recursion depth (d) and number of threads available (t):

$$t = 2^d$$

Maximum depth possible:

$$\lg\left(\frac{array\ size}{cutoff}\right)$$

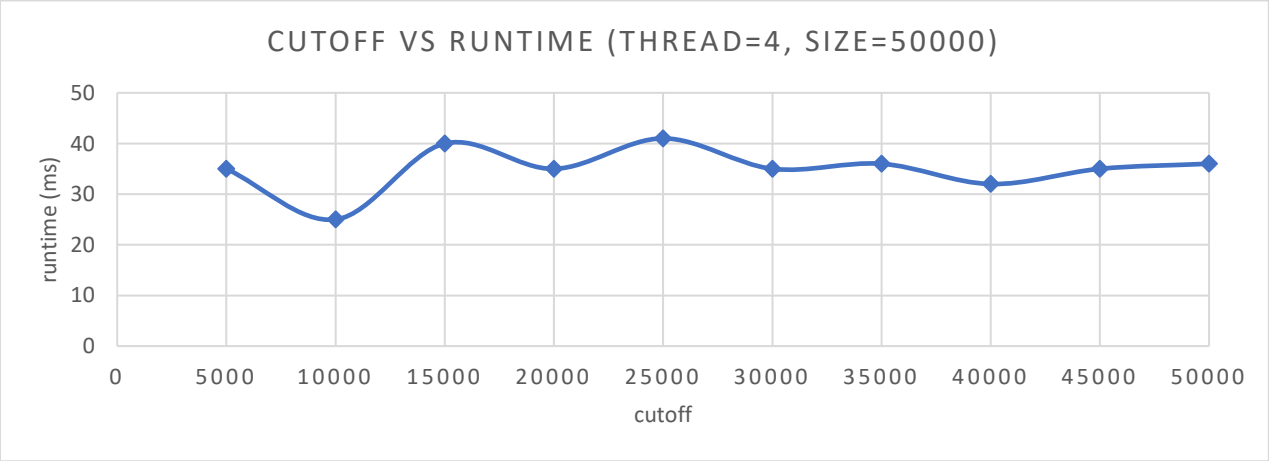
Any depth more significant than the max depth is not feasible as the partitioned arrays hit the cutoff and turned into a system sort.

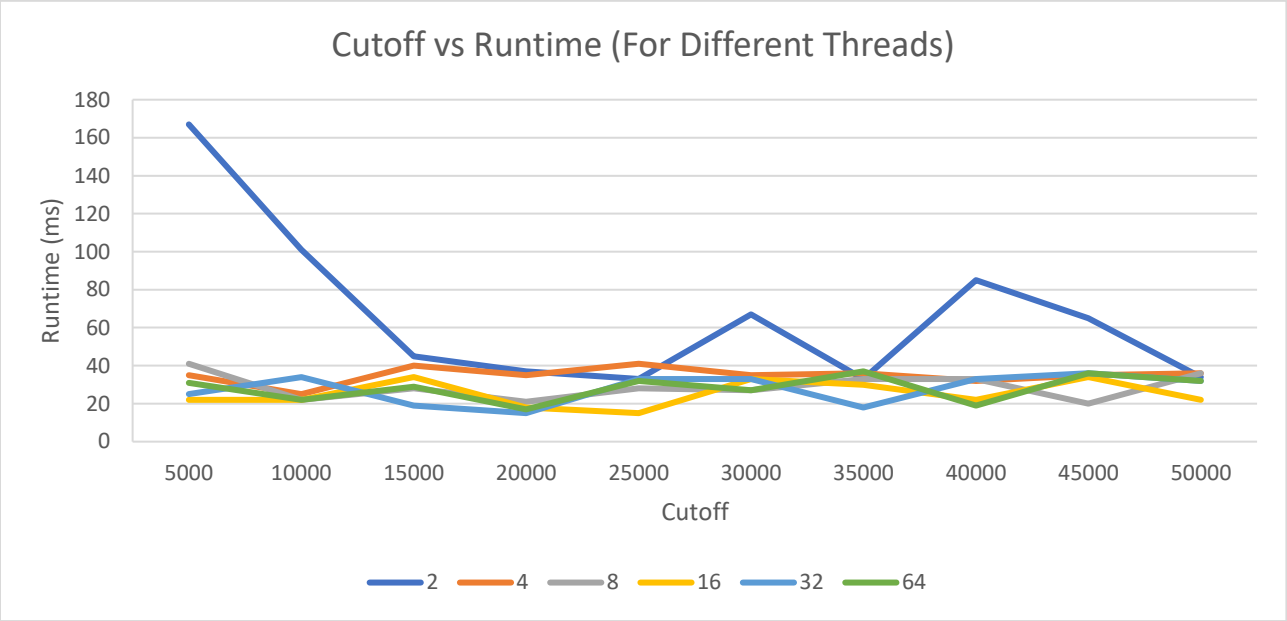
Evidence to the Conclusion

Below are the runtimes in 'ms' for different combinations of Array size, threads, and cutoffs.

Array size = 50000

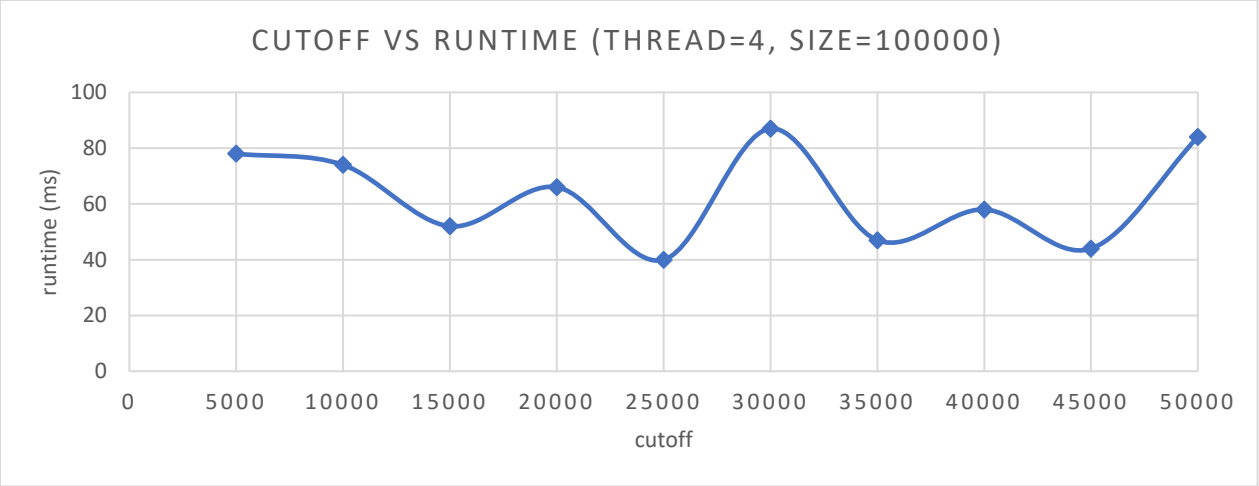
	Thread					
Cutoff	2	4	8	16	32	64
5000	167	35	41	22	25	31
10000	101	25	22	22	34	22
15000	45	40	28	34	19	29
20000	37	35	21	18	15	17
25000	33	41	28	15	33	32
30000	67	35	27	33	33	27
35000	33	36	33	30	18	37
40000	85	32	33	22	33	19
45000	65	35	20	34	36	36
50000	34	36	36	22	32	32

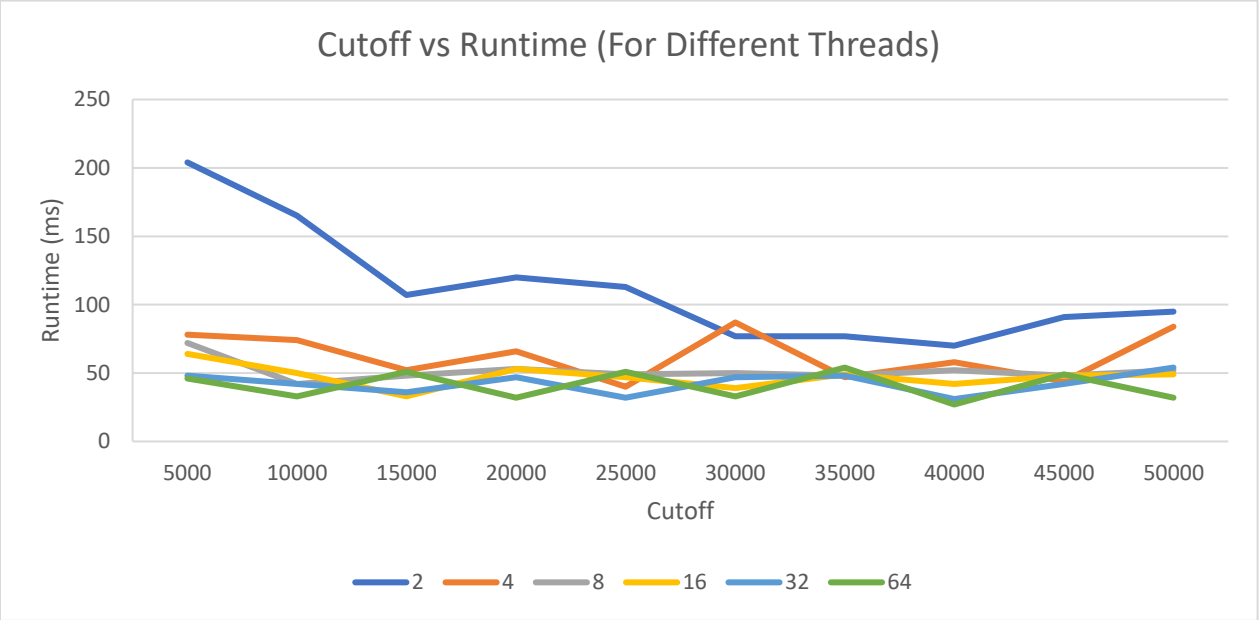




Array size = 100000

	Thread					
Cutoff	2	4	8	16	32	64
5000	204	78	72	64	48	46
10000	165	74	42	50	42	33
15000	107	52	48	33	36	51
20000	120	66	53	53	47	32
25000	113	40	49	47	32	51
30000	77	87	50	39	47	33
35000	77	47	48	49	48	54
40000	70	58	52	42	31	27
45000	91	44	48	48	42	49
50000	95	84	52	49	54	32

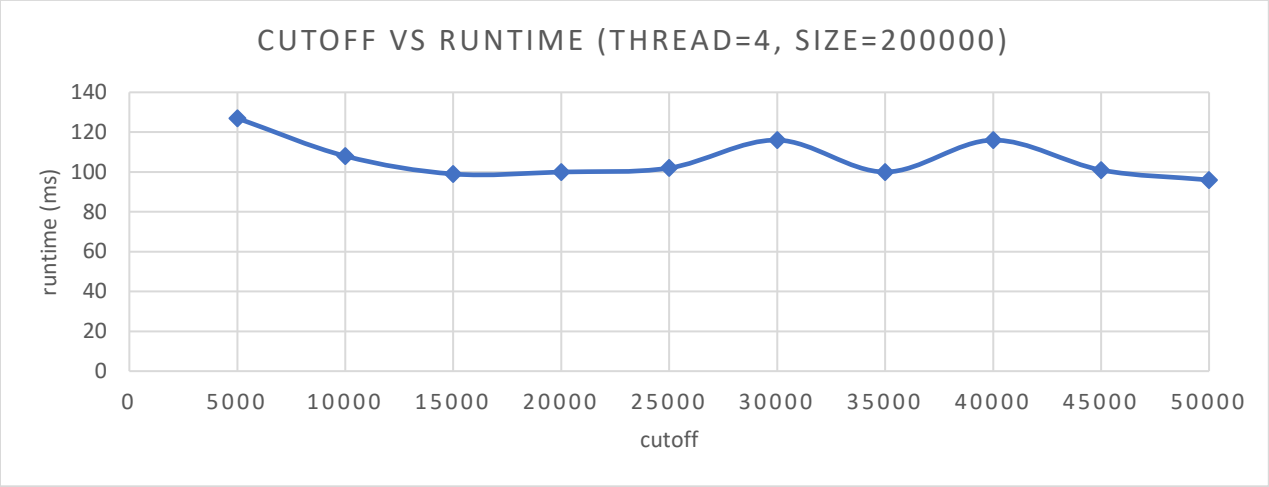


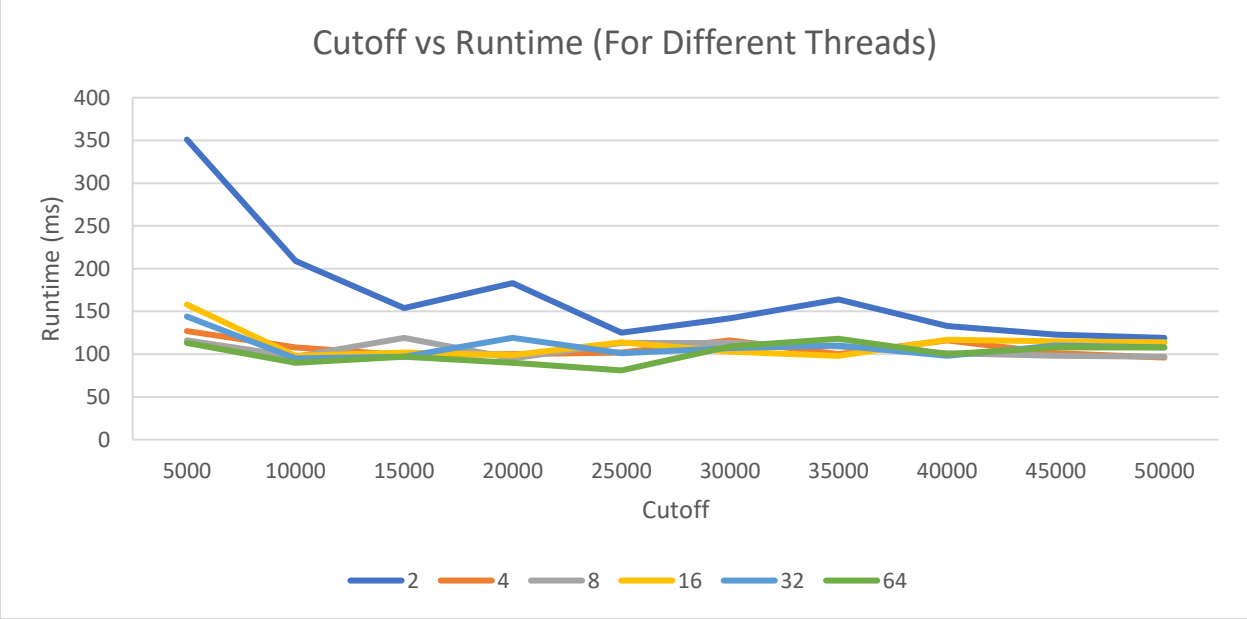


Array size = 200000

	Thread					
Cutoff	2	4	8	16	32	64
5000	351	127	116	158	144	113
10000	209	108	97	98	95	90
15000	154	99	119	102	97	97
20000	183	100	95	99	119	90
25000	125	102	113	114	101	81
30000	142	116	113	103	107	109

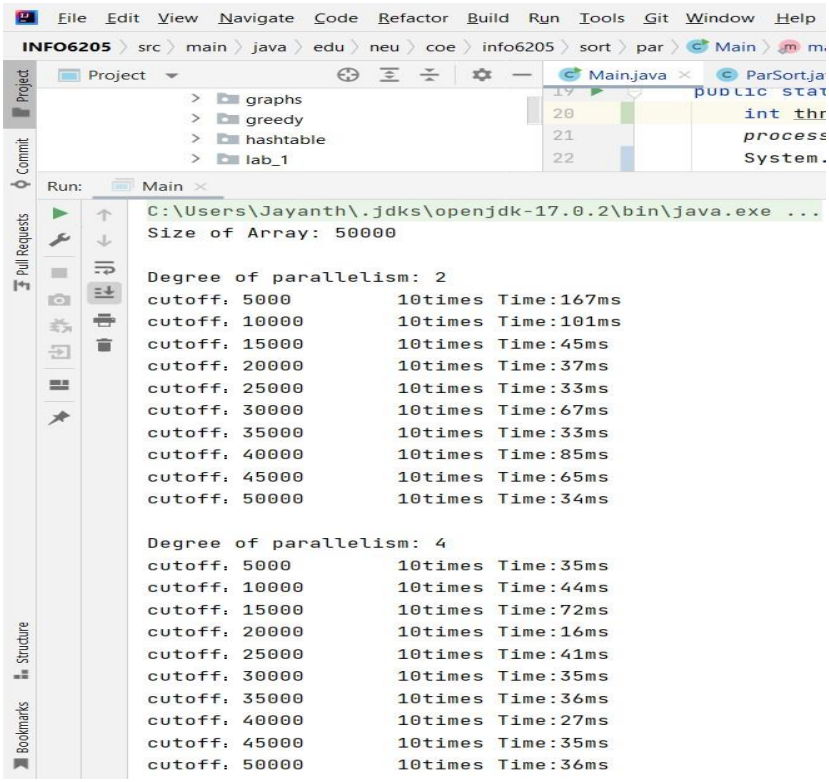
35000	164	100	109	98	110	118
40000	133	116	101	117	98	100
45000	123	101	98	115	110	108
50000	119	96	97	114	108	108

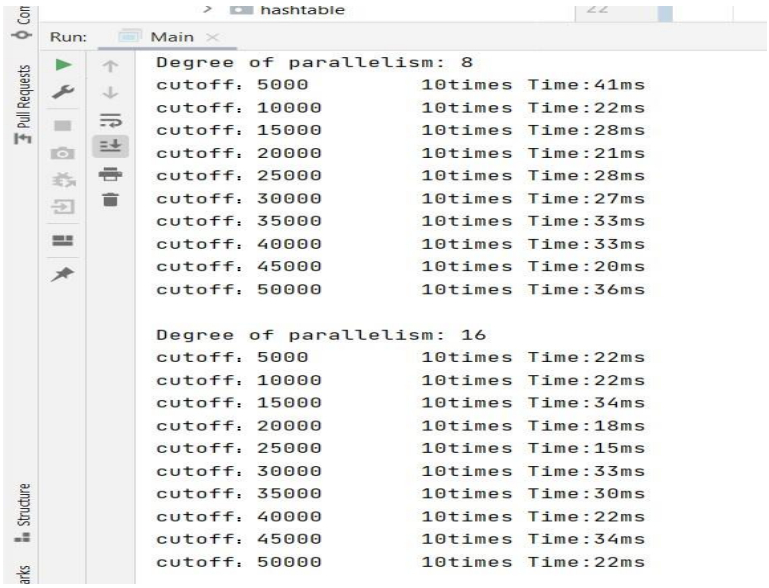


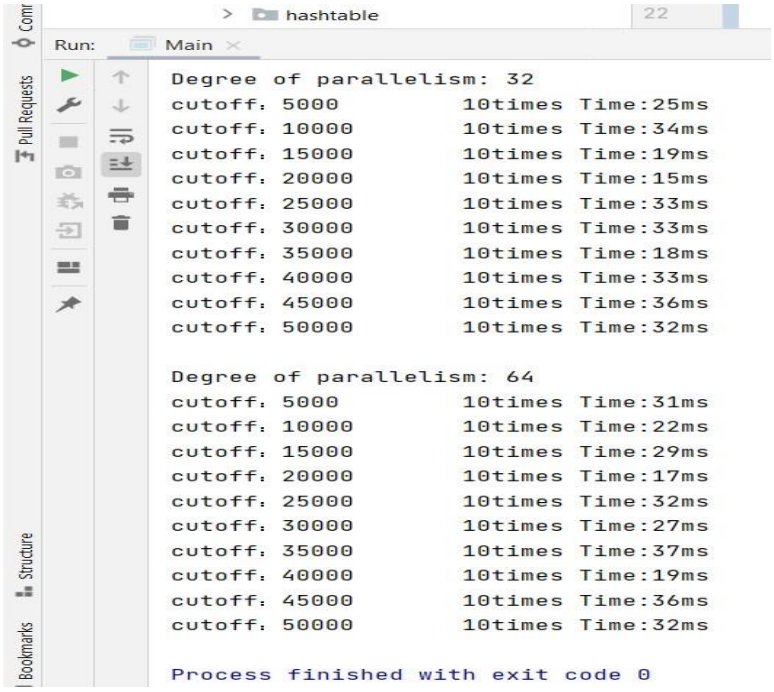


Output Screenshot

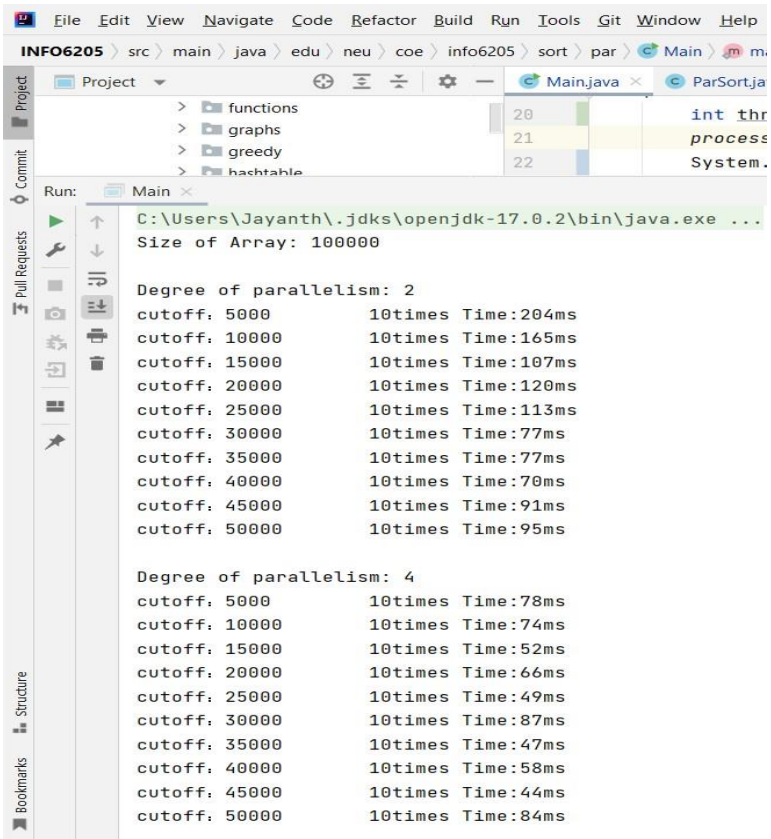
Array size = 50000

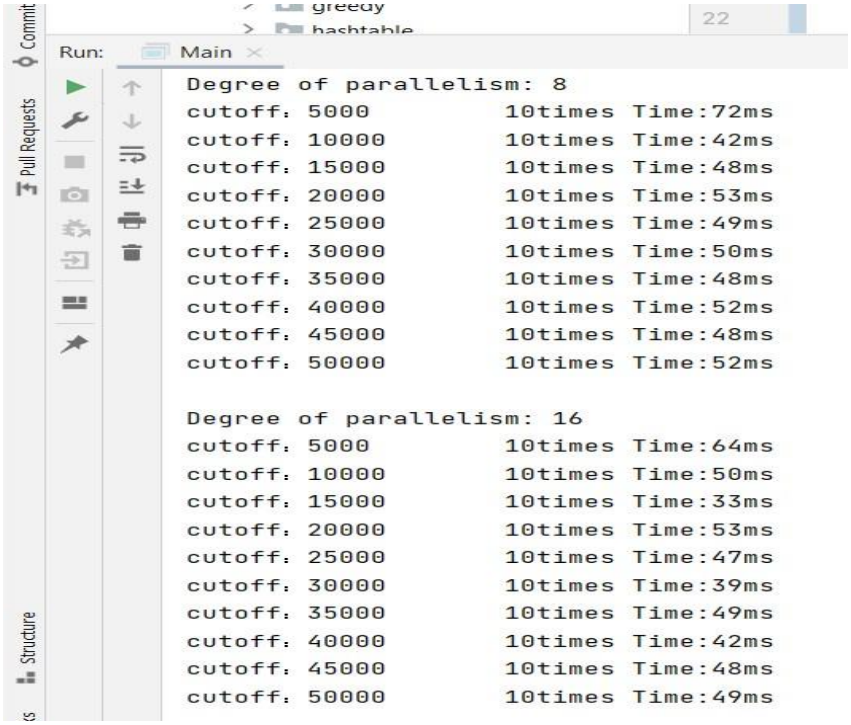


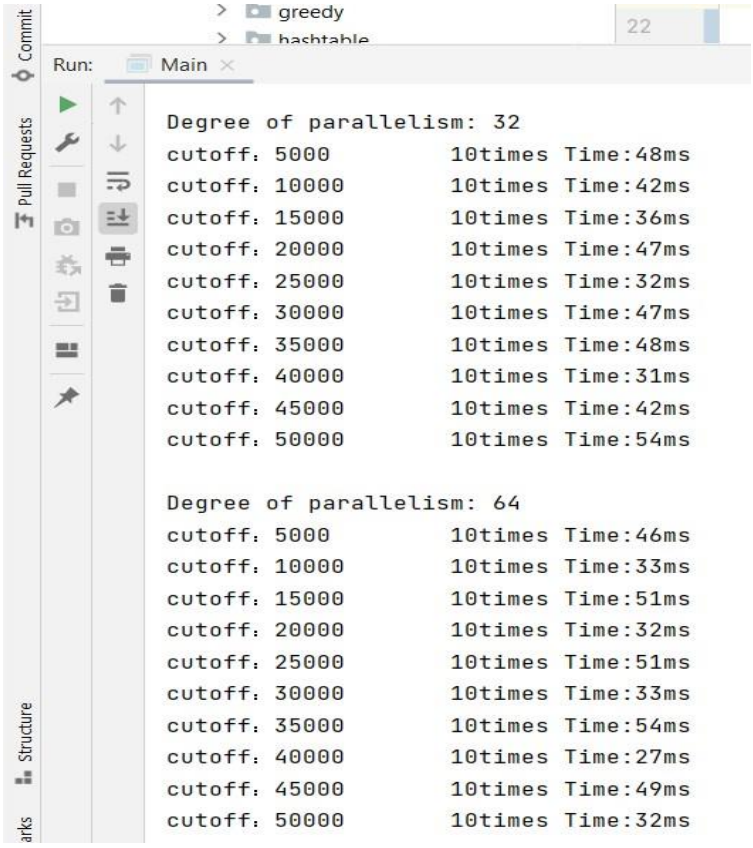




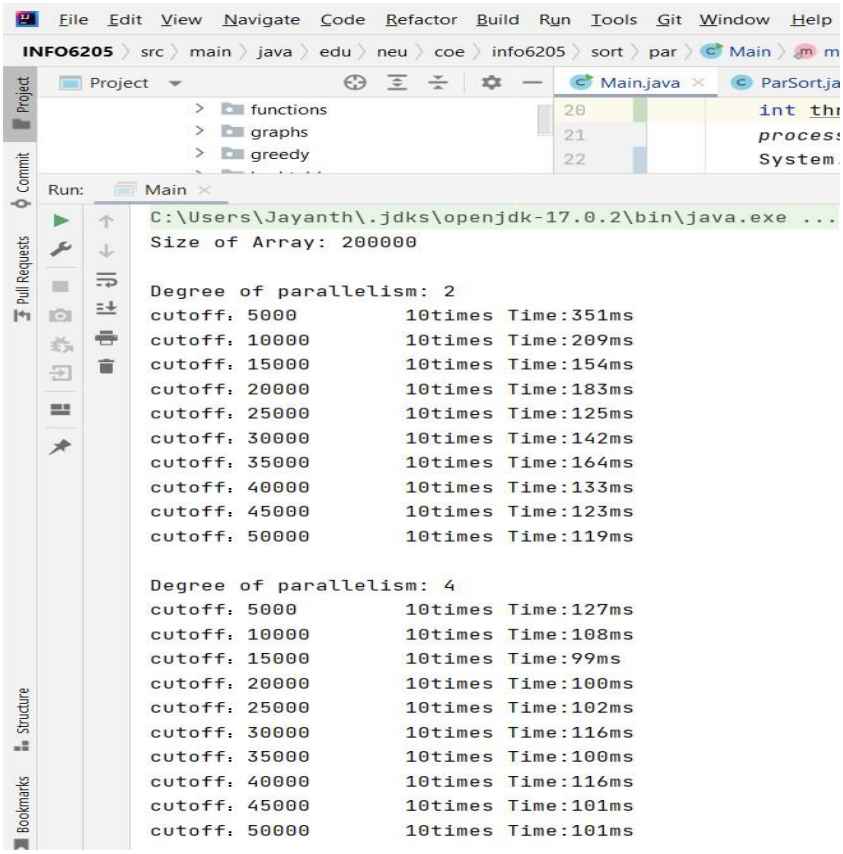
Array size = 100000

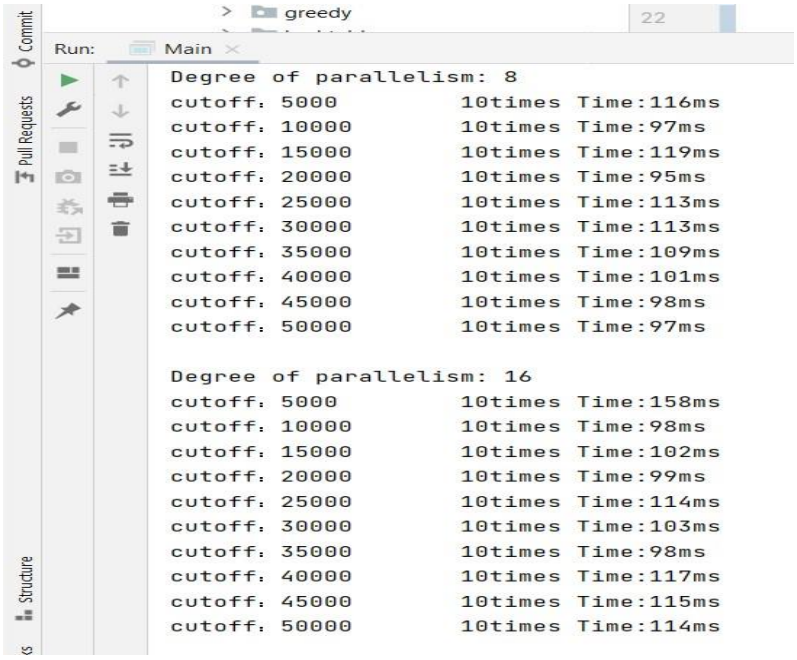


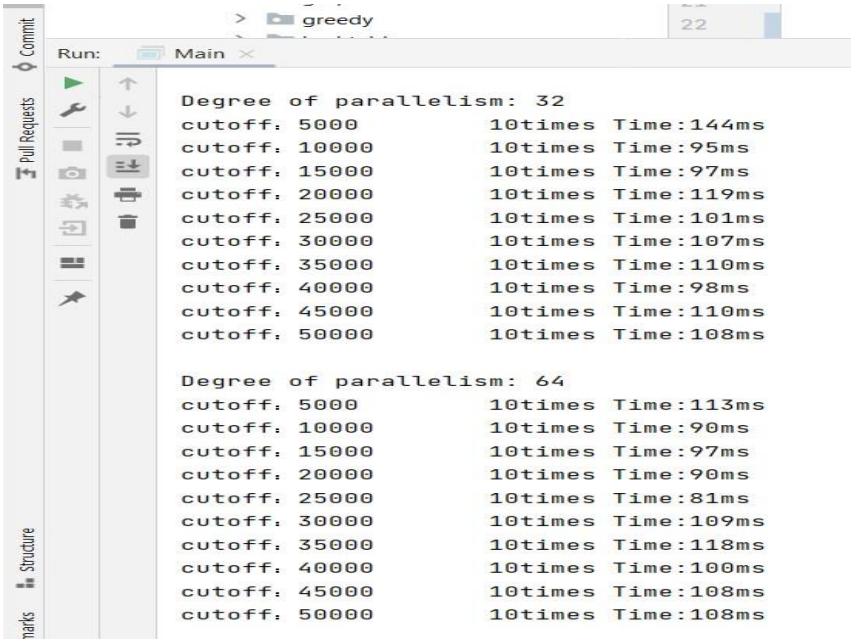

greedy
hashtable
22
Run:
Main
Degree of parallelism: 8
cutoff: 5000 10times Time:72ms
cutoff: 10000 10times Time:42ms
cutoff: 15000 10times Time:48ms
cutoff: 20000 10times Time:53ms
cutoff: 25000 10times Time:49ms
cutoff: 30000 10times Time:50ms
cutoff: 35000 10times Time:48ms
cutoff: 40000 10times Time:52ms
cutoff: 45000 10times Time:48ms
cutoff: 50000 10times Time:52ms
Degree of parallelism: 16
cutoff: 5000 10times Time:64ms
cutoff: 10000 10times Time:50ms
cutoff: 15000 10times Time:33ms
cutoff: 20000 10times Time:53ms
cutoff: 25000 10times Time:47ms
cutoff: 30000 10times Time:39ms
cutoff: 35000 10times Time:49ms
cutoff: 40000 10times Time:42ms
cutoff: 45000 10times Time:48ms
cutoff: 50000 10times Time:49ms
Commit
Pull Requests
Structure


greedy
hashtable
22
Run:
Main
Degree of parallelism: 32
cutoff: 5000 10times Time:48ms
cutoff: 10000 10times Time:42ms
cutoff: 15000 10times Time:36ms
cutoff: 20000 10times Time:47ms
cutoff: 25000 10times Time:32ms
cutoff: 30000 10times Time:47ms
cutoff: 35000 10times Time:48ms
cutoff: 40000 10times Time:31ms
cutoff: 45000 10times Time:42ms
cutoff: 50000 10times Time:54ms
Degree of parallelism: 64
cutoff: 5000 10times Time:46ms
cutoff: 10000 10times Time:33ms
cutoff: 15000 10times Time:51ms
cutoff: 20000 10times Time:32ms
cutoff: 25000 10times Time:51ms
cutoff: 30000 10times Time:33ms
cutoff: 35000 10times Time:54ms
cutoff: 40000 10times Time:27ms
cutoff: 45000 10times Time:49ms
cutoff: 50000 10times Time:32ms
Commit
Pull Requests
Structure

Array size = 200000







Output

Size of Array: 50000

Degree of parallelism: 2
cutoff：5000 10times Time:167ms
cutoff：10000 10times Time:101ms
cutoff：15000 10times Time:45ms
cutoff：20000 10times Time:37ms
cutoff：25000 10times Time:33ms
cutoff：30000 10times Time:67ms
cutoff：35000 10times Time:33ms
cutoff：40000 10times Time:85ms
cutoff：45000 10times Time:65ms
cutoff：50000 10times Time:34ms

Degree of parallelism: 4
cutoff：5000 10times Time:35ms
cutoff：10000 10times Time:44ms
cutoff：15000 10times Time:72ms
cutoff：20000 10times Time:16ms
cutoff：25000 10times Time:41ms
cutoff：30000 10times Time:35ms
cutoff：35000 10times Time:36ms
cutoff：40000 10times Time:27ms
cutoff：45000 10times Time:35ms
cutoff：50000 10times Time:36ms

Degree of parallelism: 8
cutoff : 5000 10times Time:41ms
cutoff : 10000 10times Time:22ms
cutoff : 15000 10times Time:28ms
cutoff : 20000 10times Time:21ms
cutoff : 25000 10times Time:28ms
cutoff : 30000 10times Time:27ms
cutoff : 35000 10times Time:33ms
cutoff : 40000 10times Time:33ms
cutoff : 45000 10times Time:20ms
cutoff : 50000 10times Time:36ms

Degree of parallelism: 16
cutoff : 5000 10times Time:22ms
cutoff : 10000 10times Time:22ms
cutoff : 15000 10times Time:34ms
cutoff : 20000 10times Time:18ms
cutoff : 25000 10times Time:15ms
cutoff : 30000 10times Time:33ms
cutoff : 35000 10times Time:30ms
cutoff : 40000 10times Time:22ms
cutoff : 45000 10times Time:34ms
cutoff : 50000 10times Time:22ms

Degree of parallelism: 32
cutoff : 5000 10times Time:25ms
cutoff : 10000 10times Time:34ms
cutoff : 15000 10times Time:19ms
cutoff : 20000 10times Time:15ms
cutoff : 25000 10times Time:33ms
cutoff : 30000 10times Time:33ms
cutoff : 35000 10times Time:18ms
cutoff : 40000 10times Time:33ms
cutoff : 45000 10times Time:36ms
cutoff : 50000 10times Time:32ms

Degree of parallelism: 64
cutoff : 5000 10times Time:31ms
cutoff : 10000 10times Time:22ms
cutoff : 15000 10times Time:29ms
cutoff : 20000 10times Time:17ms
cutoff : 25000 10times Time:32ms
cutoff : 30000 10times Time:27ms
cutoff : 35000 10times Time:37ms
cutoff : 40000 10times Time:19ms
cutoff : 45000 10times Time:36ms
cutoff : 50000 10times Time:32ms

Process finished with exit code 0

//

Size of Array: 100000

Degree of parallelism: 2
cutoff : 5000 10times Time:204ms
cutoff : 10000 10times Time:165ms
cutoff : 15000 10times Time:107ms
cutoff : 20000 10times Time:120ms
cutoff : 25000 10times Time:113ms
cutoff : 30000 10times Time:77ms
cutoff : 35000 10times Time:77ms
cutoff : 40000 10times Time:70ms
cutoff : 45000 10times Time:91ms
cutoff : 50000 10times Time:95ms

Degree of parallelism: 4
cutoff : 5000 10times Time:78ms
cutoff : 10000 10times Time:74ms
cutoff : 15000 10times Time:52ms
cutoff : 20000 10times Time:66ms
cutoff : 25000 10times Time:49ms
cutoff : 30000 10times Time:87ms
cutoff : 35000 10times Time:47ms
cutoff : 40000 10times Time:58ms
cutoff : 45000 10times Time:44ms
cutoff : 50000 10times Time:84ms

Degree of parallelism: 8
cutoff : 5000 10times Time:72ms
cutoff : 10000 10times Time:42ms
cutoff : 15000 10times Time:48ms
cutoff : 20000 10times Time:53ms
cutoff : 25000 10times Time:49ms
cutoff : 30000 10times Time:50ms
cutoff : 35000 10times Time:48ms
cutoff : 40000 10times Time:52ms
cutoff : 45000 10times Time:48ms
cutoff : 50000 10times Time:52ms

Degree of parallelism: 16
cutoff : 5000 10times Time:64ms
cutoff : 10000 10times Time:50ms
cutoff : 15000 10times Time:33ms
cutoff : 20000 10times Time:53ms
cutoff : 25000 10times Time:47ms
cutoff : 30000 10times Time:39ms
cutoff : 35000 10times Time:49ms
cutoff : 40000 10times Time:42ms
cutoff : 45000 10times Time:48ms

cutoff：50000 10times Time:49ms

Degree of parallelism: 32
cutoff：5000 10times Time:48ms
cutoff：10000 10times Time:42ms
cutoff：15000 10times Time:36ms
cutoff：20000 10times Time:47ms
cutoff：25000 10times Time:32ms
cutoff：30000 10times Time:47ms
cutoff：35000 10times Time:48ms
cutoff：40000 10times Time:31ms
cutoff：45000 10times Time:42ms
cutoff：50000 10times Time:54ms

Degree of parallelism: 64
cutoff：5000 10times Time:46ms
cutoff：10000 10times Time:33ms
cutoff：15000 10times Time:51ms
cutoff：20000 10times Time:32ms
cutoff：25000 10times Time:51ms
cutoff：30000 10times Time:33ms
cutoff：35000 10times Time:54ms
cutoff：40000 10times Time:27ms
cutoff：45000 10times Time:49ms
cutoff：50000 10times Time:32ms

Process finished with exit code 0

//

Size of Array: 200000

Degree of parallelism: 2
cutoff：5000 10times Time:351ms
cutoff：10000 10times Time:209ms
cutoff：15000 10times Time:154ms
cutoff：20000 10times Time:183ms
cutoff：25000 10times Time:125ms
cutoff：30000 10times Time:142ms
cutoff：35000 10times Time:164ms
cutoff：40000 10times Time:133ms
cutoff：45000 10times Time:123ms
cutoff：50000 10times Time:119ms

Degree of parallelism: 4
cutoff：5000 10times Time:127ms
cutoff：10000 10times Time:108ms
cutoff：15000 10times Time:99ms

cutoff : 20000 10times Time:100ms
cutoff : 25000 10times Time:102ms
cutoff : 30000 10times Time:116ms
cutoff : 35000 10times Time:100ms
cutoff : 40000 10times Time:116ms
cutoff : 45000 10times Time:101ms
cutoff : 50000 10times Time:101ms

Degree of parallelism: 8
cutoff : 5000 10times Time:116ms
cutoff : 10000 10times Time:97ms
cutoff : 15000 10times Time:119ms
cutoff : 20000 10times Time:95ms
cutoff : 25000 10times Time:113ms
cutoff : 30000 10times Time:113ms
cutoff : 35000 10times Time:109ms
cutoff : 40000 10times Time:101ms
cutoff : 45000 10times Time:98ms
cutoff : 50000 10times Time:97ms

Degree of parallelism: 16
cutoff : 5000 10times Time:158ms
cutoff : 10000 10times Time:98ms
cutoff : 15000 10times Time:102ms
cutoff : 20000 10times Time:99ms
cutoff : 25000 10times Time:114ms
cutoff : 30000 10times Time:103ms
cutoff : 35000 10times Time:98ms
cutoff : 40000 10times Time:117ms
cutoff : 45000 10times Time:115ms
cutoff : 50000 10times Time:114ms

Degree of parallelism: 32
cutoff : 5000 10times Time:144ms
cutoff : 10000 10times Time:95ms
cutoff : 15000 10times Time:97ms
cutoff : 20000 10times Time:119ms
cutoff : 25000 10times Time:101ms
cutoff : 30000 10times Time:107ms
cutoff : 35000 10times Time:110ms
cutoff : 40000 10times Time:98ms
cutoff : 45000 10times Time:110ms
cutoff : 50000 10times Time:108ms

Degree of parallelism: 64
cutoff : 5000 10times Time:113ms
cutoff : 10000 10times Time:90ms
cutoff : 15000 10times Time:97ms
cutoff : 20000 10times Time:90ms
cutoff : 25000 10times Time:81ms

```
cutoff：30000		10times Time:109ms
cutoff：35000		10times Time:118ms
cutoff：40000		10times Time:100ms
cutoff：45000		10times Time:108ms
cutoff：50000		10times Time:108ms

Process finished with exit code 0
```