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Program Structures & Algorithms

Fall 2021

Assignment No. 5

⊙ Task (List down the tasks performed in the Assignment)

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. It is better to sort in parallel than system sort
2. A good cutoff number is around 41% of the array size
3. An ideal number of separate threads is 8

⊙ Evidence to support the conclusion:

1. Output

```
public static void main(String[] args) {
    processArgs(args);
    System.out.println("------------test cutoff-------------");
    System.out.println("Degree of parallelism: " + ForkJoinPool.getCommonPoolParallelism());
    Random random = new Random();
    // manually set the array size from 2000000 to 5000000
    int[] array = new int[5000000]; // 2000000, 3000000, 4000000, 5000000
```

Firstly, I tested the relationship between run time and cutoff number. As ForkJoinPool. get-CommonPoolParallelism() was 7 which told me my cpu is 8, I chose thread number as 8 at

first to test different cutoff results. The output was long, so I just screenshot the part of the result.

the array size from 2000000 to 5000000, the cutoff from 25.5% to 50% of array size

```
Degree of parallelism: 7
the number of threads is: 8
cutoff: 510000      10times Time:975ms
cutoff: 520000      10times Time:816ms
cutoff: 530000      10times Time:809ms
cutoff: 540000      10times Time:863ms
cutoff: 550000      10times Time:865ms
cutoff: 560000      10times Time:906ms
cutoff: 570000      10times Time:899ms
cutoff: 580000      10times Time:846ms
cutoff: 590000      10times Time:862ms
cutoff: 600000      10times Time:847ms
cutoff: 610000      10times Time:813ms
cutoff: 620000      10times Time:825ms
cutoff: 630000      10times Time:872ms
cutoff: 640000      10times Time:838ms
cutoff: 650000      10times Time:834ms
cutoff: 660000      10times Time:850ms
cutoff: 670000      10times Time:849ms
cutoff: 680000      10times Time:838ms
cutoff: 690000      10times Time:844ms
cutoff: 700000      10times Time:873ms
cutoff: 710000      10times Time:841ms
cutoff: 720000      10times Time:932ms
cutoff: 730000      10times Time:842ms
cutoff: 740000      10times Time:874ms
cutoff: 750000      10times Time:840ms
cutoff: 760000      10times Time:836ms
cutoff: 770000      10times Time:929ms
cutoff: 780000      10times Time:873ms
cutoff: 790000      10times Time:863ms
cutoff: 800000      10times Time:931ms
cutoff: 810000      10times Time:855ms
cutoff: 820000      10times Time:844ms
cutoff: 830000      10times Time:871ms
cutoff: 840000      10times Time:904ms
cutoff: 850000      10times Time:877ms
cutoff: 860000      10times Time:858ms
cutoff: 870000      10times Time:872ms
cutoff: 880000      10times Time:860ms
```

```
Degree of parallelism: 7
the number of threads is: 8
cutoff: 765000      10times Time:1634ms
cutoff: 780000      10times Time:1293ms
cutoff: 795000      10times Time:1280ms
cutoff: 810000      10times Time:1279ms
cutoff: 825000      10times Time:1275ms
cutoff: 840000      10times Time:1276ms
cutoff: 855000      10times Time:1284ms
cutoff: 870000      10times Time:1319ms
cutoff: 885000      10times Time:1327ms
cutoff: 900000      10times Time:1307ms
cutoff: 915000      10times Time:1457ms
cutoff: 930000      10times Time:1433ms
cutoff: 945000      10times Time:1410ms
cutoff: 960000      10times Time:1602ms
cutoff: 975000      10times Time:1367ms
cutoff: 990000      10times Time:1407ms
cutoff: 1005000     10times Time:1385ms
cutoff: 1020000     10times Time:1379ms
cutoff: 1035000     10times Time:1403ms
cutoff: 1050000     10times Time:1392ms
cutoff: 1065000     10times Time:1358ms
cutoff: 1080000     10times Time:1400ms
cutoff: 1095000     10times Time:1462ms
cutoff: 1110000     10times Time:1359ms
cutoff: 1125000     10times Time:1321ms
cutoff: 1140000     10times Time:1321ms
cutoff: 1155000     10times Time:1329ms
cutoff: 1170000     10times Time:1316ms
cutoff: 1185000     10times Time:1317ms
cutoff: 1200000     10times Time:1310ms
cutoff: 1215000     10times Time:1290ms
cutoff: 1230000     10times Time:1281ms
cutoff: 1245000     10times Time:1274ms
cutoff: 1260000     10times Time:1275ms
cutoff: 1275000     10times Time:1280ms
cutoff: 1290000     10times Time:1281ms
cutoff: 1305000     10times Time:1276ms
cutoff: 1320000     10times Time:1276ms
```

```
Degree of parallelism: 7
the number of threads is: 8
cutoff: 1020000     10times Time:2077ms
cutoff: 1040000     10times Time:1738ms
cutoff: 1060000     10times Time:1770ms
cutoff: 1080000     10times Time:1719ms
cutoff: 1100000     10times Time:1749ms
cutoff: 1120000     10times Time:1747ms
cutoff: 1140000     10times Time:1796ms
cutoff: 1160000     10times Time:1955ms
cutoff: 1180000     10times Time:1902ms
cutoff: 1200000     10times Time:1832ms
cutoff: 1220000     10times Time:1818ms
cutoff: 1240000     10times Time:1800ms
cutoff: 1260000     10times Time:1776ms
cutoff: 1280000     10times Time:1811ms
cutoff: 1300000     10times Time:1892ms
cutoff: 1320000     10times Time:1858ms
cutoff: 1340000     10times Time:1872ms
cutoff: 1360000     10times Time:1741ms
cutoff: 1380000     10times Time:1732ms
cutoff: 1400000     10times Time:1725ms
cutoff: 1420000     10times Time:1727ms
cutoff: 1440000     10times Time:1750ms
cutoff: 1460000     10times Time:1728ms
cutoff: 1480000     10times Time:1738ms
cutoff: 1500000     10times Time:1735ms
cutoff: 1520000     10times Time:1729ms
cutoff: 1540000     10times Time:1742ms
cutoff: 1560000     10times Time:1730ms
cutoff: 1580000     10times Time:1728ms
cutoff: 1600000     10times Time:1730ms
cutoff: 1620000     10times Time:1726ms
cutoff: 1640000     10times Time:1728ms
cutoff: 1660000     10times Time:1800ms
cutoff: 1680000     10times Time:2002ms
cutoff: 1700000     10times Time:1802ms
cutoff: 1720000     10times Time:1743ms
cutoff: 1740000     10times Time:1785ms
cutoff: 1760000     10times Time:1904ms
```

```
Degree of parallelism: 7
the number of threads is: 8
cutoff: 1275000     10times Time:2381ms
cutoff: 1300000     10times Time:2166ms
cutoff: 1325000     10times Time:2157ms
cutoff: 1350000     10times Time:2163ms
cutoff: 1375000     10times Time:2152ms
cutoff: 1400000     10times Time:2139ms
cutoff: 1425000     10times Time:2238ms
cutoff: 1450000     10times Time:2263ms
cutoff: 1475000     10times Time:2193ms
cutoff: 1500000     10times Time:2213ms
cutoff: 1525000     10times Time:2234ms
cutoff: 1550000     10times Time:2230ms
cutoff: 1575000     10times Time:2430ms
cutoff: 1600000     10times Time:2287ms
cutoff: 1625000     10times Time:2288ms
cutoff: 1650000     10times Time:2282ms
cutoff: 1675000     10times Time:2284ms
cutoff: 1700000     10times Time:2507ms
cutoff: 1725000     10times Time:2423ms
cutoff: 1750000     10times Time:2189ms
cutoff: 1775000     10times Time:2183ms
cutoff: 1800000     10times Time:2178ms
cutoff: 1825000     10times Time:2225ms
cutoff: 1850000     10times Time:2220ms
cutoff: 1875000     10times Time:2214ms
cutoff: 1900000     10times Time:2290ms
cutoff: 1925000     10times Time:2292ms
cutoff: 1950000     10times Time:2116ms
cutoff: 1975000     10times Time:2138ms
cutoff: 2000000     10times Time:2106ms
cutoff: 2025000     10times Time:2134ms
cutoff: 2050000     10times Time:2104ms
cutoff: 2075000     10times Time:2130ms
cutoff: 2100000     10times Time:2130ms
cutoff: 2125000     10times Time:2142ms
cutoff: 2150000     10times Time:2101ms
cutoff: 2175000     10times Time:2221ms
cutoff: 2200000     10times Time:2155ms
```

Secondly, I made an experiment on different thread numbers with a good cutoff which is 41% of the array size.

the array size from 2000000 to 5000000, the thread number from 2 to 256

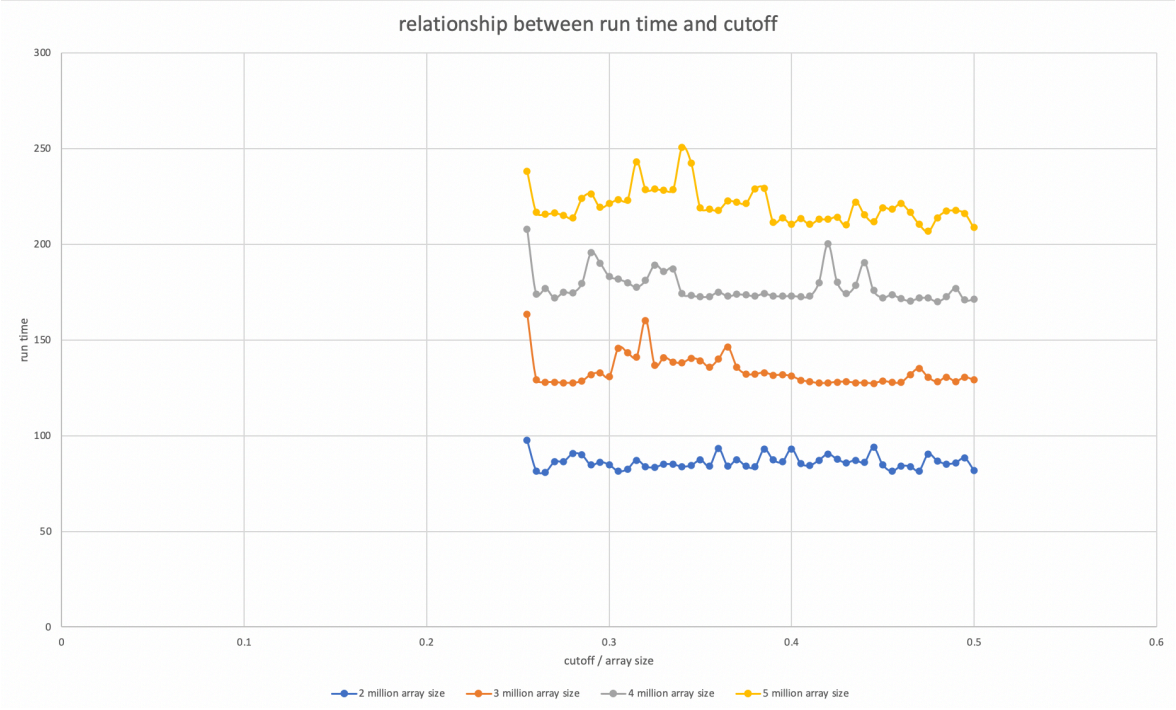
```
------------test threads-------------
the number of threads: 2        10times Time:1725ms
the number of threads: 4        10times Time:1206ms
the number of threads: 8        10times Time:797ms
the number of threads: 16       10times Time:799ms
the number of threads: 32       10times Time:816ms
the number of threads: 64       10times Time:798ms
the number of threads: 128      10times Time:814ms
the number of threads: 256      10times Time:803ms
```

```
------------test threads-------------
the number of threads: 2        10times Time:2939ms
the number of threads: 4        10times Time:1876ms
the number of threads: 8        10times Time:1224ms
the number of threads: 16       10times Time:1233ms
the number of threads: 32       10times Time:1215ms
the number of threads: 64       10times Time:1202ms
the number of threads: 128      10times Time:1217ms
the number of threads: 256      10times Time:1198ms
```

```
------------test threads-------------
the number of threads: 2        10times Time:4094ms
the number of threads: 4        10times Time:2829ms
the number of threads: 8        10times Time:1759ms
the number of threads: 16       10times Time:1712ms
the number of threads: 32       10times Time:1714ms
the number of threads: 64       10times Time:1722ms
the number of threads: 128      10times Time:1727ms
the number of threads: 256      10times Time:1746ms
```

```
------------test threads-------------
the number of threads: 2        10times Time:5247ms
the number of threads: 4        10times Time:3484ms
the number of threads: 8        10times Time:2308ms
the number of threads: 16       10times Time:2271ms
the number of threads: 32       10times Time:2226ms
the number of threads: 64       10times Time:2274ms
the number of threads: 128      10times Time:2234ms
the number of threads: 256      10times Time:2288ms
```

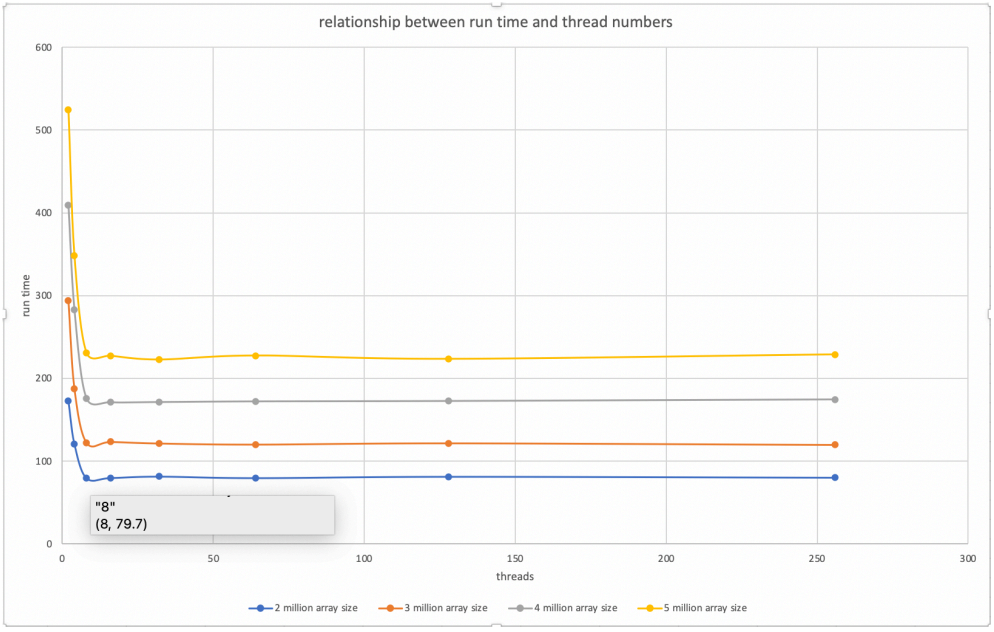
2. **Graphical Representation**



cutoff / array size	2 million array size	3 million array size	4 million array size	5 million array size
0.255	97.5	163.4	207.7	238.1
0.26	81.6	129.3	173.8	216.6
0.265	80.9	128	177	215.7
0.27	86.3	127.9	171.9	216.3
0.275	86.5	127.5	174.9	215.2
0.28	90.6	127.6	174.7	213.9
0.285	89.9	128.4	179.6	223.8
0.29	84.6	131.9	195.5	226.3
0.295	86.2	132.7	190.2	219.3
0.3	84.7	130.7	183.2	221.3
0.305	81.3	145.7	181.8	223.4
0.31	82.5	143.3	180	223
0.315	87.2	141	177.6	243
0.32	83.8	160.2	181.1	228.7
0.325	83.4	136.7	189.2	228.8
0.33	85	140.7	185.8	228.2
0.335	84.9	138.5	187.2	228.4
0.34	83.8	137.9	174.1	250.7
0.345	84.4	140.3	173.2	242.3
0.35	87.3	139.2	172.5	218.9
0.355	84.1	135.8	172.7	218.3
0.36	93.2	140	175	217.8
0.365	84.2	146.2	172.8	222.5
0.37	87.4	135.9	173.8	222
0.375	84	132.1	173.5	221.4
0.38	83.6	132.1	172.9	229
0.385	92.9	132.9	174.2	229.2
0.39	87.3	131.6	173	211.6
0.395	86.3	131.7	172.8	213.8
0.4	93.1	131	173	210.6
0.405	85.5	129	172.6	213.4
0.41	84.4	128.1	172.8	210.4
0.415	87.1	127.4	180	213
0.42	90.4	127.5	200.2	213
0.425	87.7	128	180.2	214.2
0.43	85.8	128.1	174.3	210.1
0.435	87.2	127.6	178.5	222.1
0.44	86	127.6	190.4	215.5
0.445	93.8	127.3	175.8	211.8
0.45	84.8	128.4	172.1	219
0.455	81.3	127.8	173.6	218.2
0.46	84	127.7	171.6	221.2
0.465	83.9	131.7	170.4	216.7
0.47	81.6	135	171.8	210.5
0.475	90.3	130.4	171.9	206.7
0.48	86.8	128.1	170	213.9
0.485	85.2	130.5	172.6	217.3
0.49	85.8	128.3	176.9	217.6
0.495	88.2	130.4	170.8	216.2
0.5	81.9	129.1	171.2	208.7

I chose cutoff / array size = 0.41 as a relatively good value.

threads	2 million array size	3 million array size	4 million array size	5 million array size
2	172.5	293.9	409.4	524.7
4	120.6	187.6	282.9	348.4
8	79.7	122.4	175.9	230.8
16	79.9	123.3	171.2	227.1
32	81.6	121.5	171.4	222.6
64	79.8	120.2	172.2	227.4
128	81.4	121.7	172.7	223.4
256	80.3	119.8	174.6	228.8



when the thread number is larger than 8, the run time is smaller and starts to flatten.