

Program Structures & Algorithms

Fall 2021

Assignment No. 5

Tasks:

1. Implemented ForkJoinPool object instantiation in Main.java to set the number of threads to be made available.
2. Conducted experiments to determine what size of arrays justifies a parallel sort (large sized arrays work best)
3. Conducted experiments on a large sized array for cut-off values in three regions: near the start of length; near half the length; near the end of length.
4. Conducted above experiments on thread sizes ranging from 2, 4, 8 and 16.
5. Documented readings

Screenshots and Tabulations:

USE CASE: Array Size (N) = 11_400_000

For number of threads = 2 :

a) Cutoff towards the start of the length

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 2
ArraySize: 11400000 Cutoff : 1530000 Time:1567ms
ArraySize: 11400000 Cutoff : 1560000 Time:1552ms
ArraySize: 11400000 Cutoff : 1590000 Time:1255ms
ArraySize: 11400000 Cutoff : 1620000 Time:1264ms
ArraySize: 11400000 Cutoff : 1650000 Time:1192ms
ArraySize: 11400000 Cutoff : 1680000 Time:1319ms
ArraySize: 11400000 Cutoff : 1710000 Time:1378ms
ArraySize: 11400000 Cutoff : 1740000 Time:1203ms
ArraySize: 11400000 Cutoff : 1770000 Time:1192ms
ArraySize: 11400000 Cutoff : 1800000 Time:1360ms
ArraySize: 11400000 Cutoff : 1830000 Time:1351ms
ArraySize: 11400000 Cutoff : 1860000 Time:1531ms
ArraySize: 11400000 Cutoff : 1890000 Time:1341ms
ArraySize: 11400000 Cutoff : 1920000 Time:1191ms
ArraySize: 11400000 Cutoff : 1950000 Time:1182ms
ArraySize: 11400000 Cutoff : 1980000 Time:1188ms
ArraySize: 11400000 Cutoff : 2010000 Time:1481ms
ArraySize: 11400000 Cutoff : 2040000 Time:1231ms
ArraySize: 11400000 Cutoff : 2070000 Time:1271ms
ArraySize: 11400000 Cutoff : 2100000 Time:1318ms
ArraySize: 11400000 Cutoff : 2130000 Time:1374ms
ArraySize: 11400000 Cutoff : 2160000 Time:1355ms
ArraySize: 11400000 Cutoff : 2190000 Time:1584ms
```

b) Cutoff towards half the length

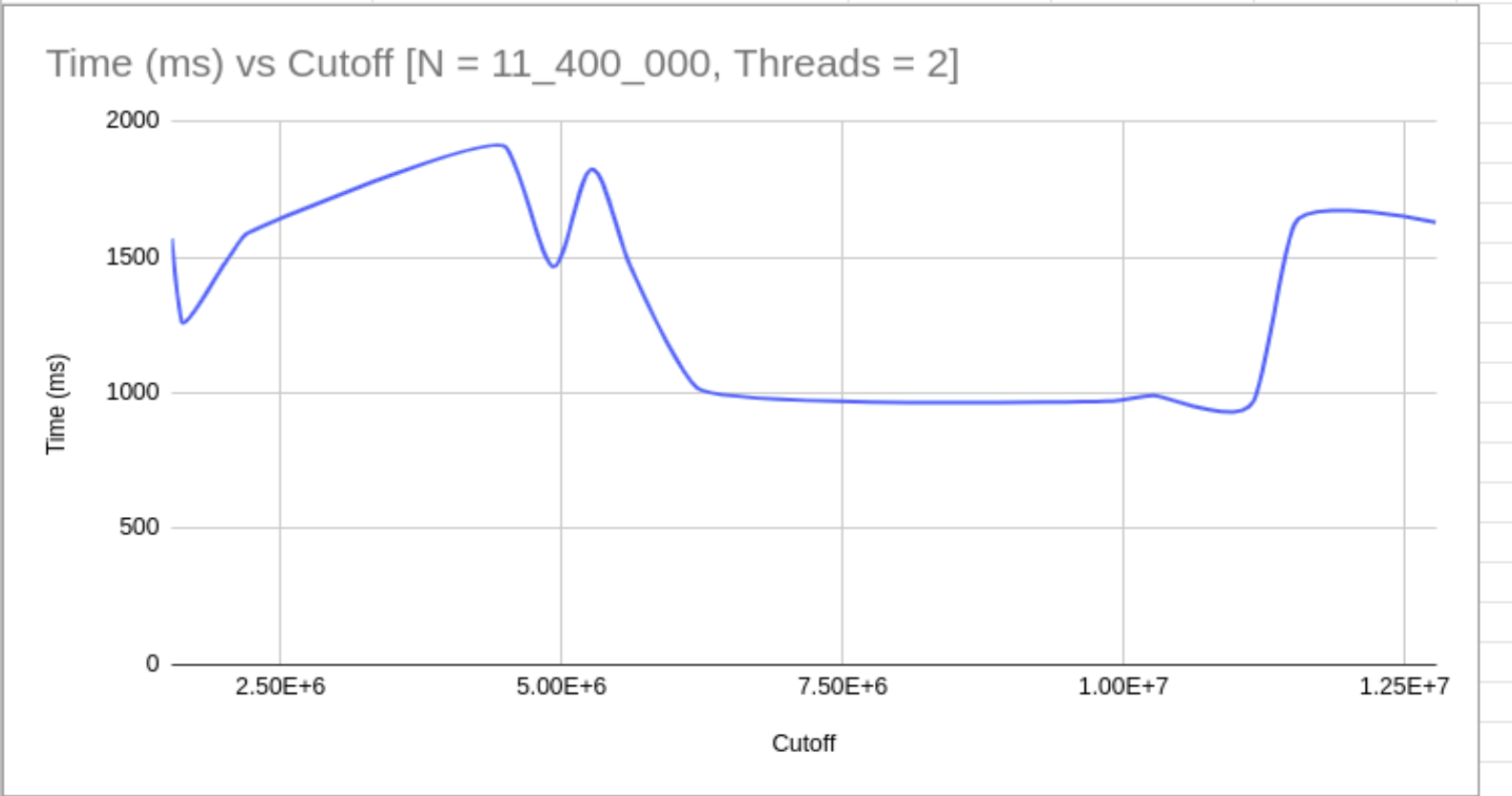
```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 2
ArraySize: 11400000 Cutoff : 4335000 Time:2015ms
ArraySize: 11400000 Cutoff : 4420000 Time:1516ms
ArraySize: 11400000 Cutoff : 4505000 Time:1905ms
ArraySize: 11400000 Cutoff : 4590000 Time:1856ms
ArraySize: 11400000 Cutoff : 4675000 Time:1868ms
ArraySize: 11400000 Cutoff : 4760000 Time:1862ms
ArraySize: 11400000 Cutoff : 4845000 Time:1846ms
ArraySize: 11400000 Cutoff : 4930000 Time:1465ms
ArraySize: 11400000 Cutoff : 5015000 Time:1864ms
ArraySize: 11400000 Cutoff : 5100000 Time:1516ms
ArraySize: 11400000 Cutoff : 5185000 Time:1829ms
ArraySize: 11400000 Cutoff : 5270000 Time:1824ms
ArraySize: 11400000 Cutoff : 5355000 Time:1844ms
ArraySize: 11400000 Cutoff : 5440000 Time:1456ms
ArraySize: 11400000 Cutoff : 5525000 Time:1463ms
ArraySize: 11400000 Cutoff : 5610000 Time:1468ms
ArraySize: 11400000 Cutoff : 5695000 Time:1509ms
ArraySize: 11400000 Cutoff : 5780000 Time:1026ms
ArraySize: 11400000 Cutoff : 5865000 Time:1022ms
ArraySize: 11400000 Cutoff : 5950000 Time:1015ms
ArraySize: 11400000 Cutoff : 6035000 Time:1043ms
ArraySize: 11400000 Cutoff : 6120000 Time:1023ms
ArraySize: 11400000 Cutoff : 6205000 Time:1019ms
```

c) Cutoff towards the end of the length

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 2
ArraySize: 11400000 Cutoff : 9180000 Time:1150ms
ArraySize: 11400000 Cutoff : 9360000 Time:1000ms
ArraySize: 11400000 Cutoff : 9540000 Time:970ms
ArraySize: 11400000 Cutoff : 9720000 Time:982ms
ArraySize: 11400000 Cutoff : 9900000 Time:970ms
ArraySize: 11400000 Cutoff : 10080000 Time:957ms
ArraySize: 11400000 Cutoff : 10260000 Time:995ms
ArraySize: 11400000 Cutoff : 10440000 Time:1009ms
ArraySize: 11400000 Cutoff : 10620000 Time:990ms
ArraySize: 11400000 Cutoff : 10800000 Time:1005ms
ArraySize: 11400000 Cutoff : 10980000 Time:961ms
ArraySize: 11400000 Cutoff : 11160000 Time:972ms
ArraySize: 11400000 Cutoff : 11340000 Time:1001ms
ArraySize: 11400000 Cutoff : 11520000 Time:1622ms
ArraySize: 11400000 Cutoff : 11700000 Time:1635ms
ArraySize: 11400000 Cutoff : 11880000 Time:1624ms
ArraySize: 11400000 Cutoff : 12060000 Time:1587ms
ArraySize: 11400000 Cutoff : 12240000 Time:1619ms
ArraySize: 11400000 Cutoff : 12420000 Time:1616ms
ArraySize: 11400000 Cutoff : 12600000 Time:1620ms
ArraySize: 11400000 Cutoff : 12780000 Time:1628ms
ArraySize: 11400000 Cutoff : 12960000 Time:1617ms
ArraySize: 11400000 Cutoff : 13140000 Time:1622ms
```

Tabulation:

A	B	C	D	E	
Cutoff	Time (ms)				
1530000	1567				
1620000	1264				
2010000	1481				
2190000	1584				
4505000	1905				
4930000	1465				
5270000	1824				
5610000	1468	Halfway mark			
6205000	1019				
9900000	970				
10260000	990				
11160000	972				
11520000	1622				
12780000	1628				



For number of threads = 4 :

a) Cutoff towards the start of length

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 4
ArraySize: 11400000 Cutoff : 1020000 Time:1605ms
ArraySize: 11400000 Cutoff : 1040000 Time:1086ms
ArraySize: 11400000 Cutoff : 1060000 Time:1226ms
ArraySize: 11400000 Cutoff : 1080000 Time:1026ms
ArraySize: 11400000 Cutoff : 1100000 Time:1039ms
ArraySize: 11400000 Cutoff : 1120000 Time:1040ms
ArraySize: 11400000 Cutoff : 1140000 Time:1040ms
ArraySize: 11400000 Cutoff : 1160000 Time:1043ms
ArraySize: 11400000 Cutoff : 1180000 Time:1092ms
ArraySize: 11400000 Cutoff : 1200000 Time:1111ms
ArraySize: 11400000 Cutoff : 1220000 Time:1287ms
ArraySize: 11400000 Cutoff : 1240000 Time:1140ms
ArraySize: 11400000 Cutoff : 1260000 Time:1080ms
ArraySize: 11400000 Cutoff : 1280000 Time:1173ms
ArraySize: 11400000 Cutoff : 1300000 Time:1149ms
ArraySize: 11400000 Cutoff : 1320000 Time:974ms
ArraySize: 11400000 Cutoff : 1340000 Time:985ms
ArraySize: 11400000 Cutoff : 1360000 Time:1302ms
ArraySize: 11400000 Cutoff : 1380000 Time:1050ms
ArraySize: 11400000 Cutoff : 1400000 Time:1116ms
ArraySize: 11400000 Cutoff : 1420000 Time:1119ms
ArraySize: 11400000 Cutoff : 1440000 Time:1114ms
ArraySize: 11400000 Cutoff : 1460000 Time:1276ms
```

b) Cutoff towards half of length

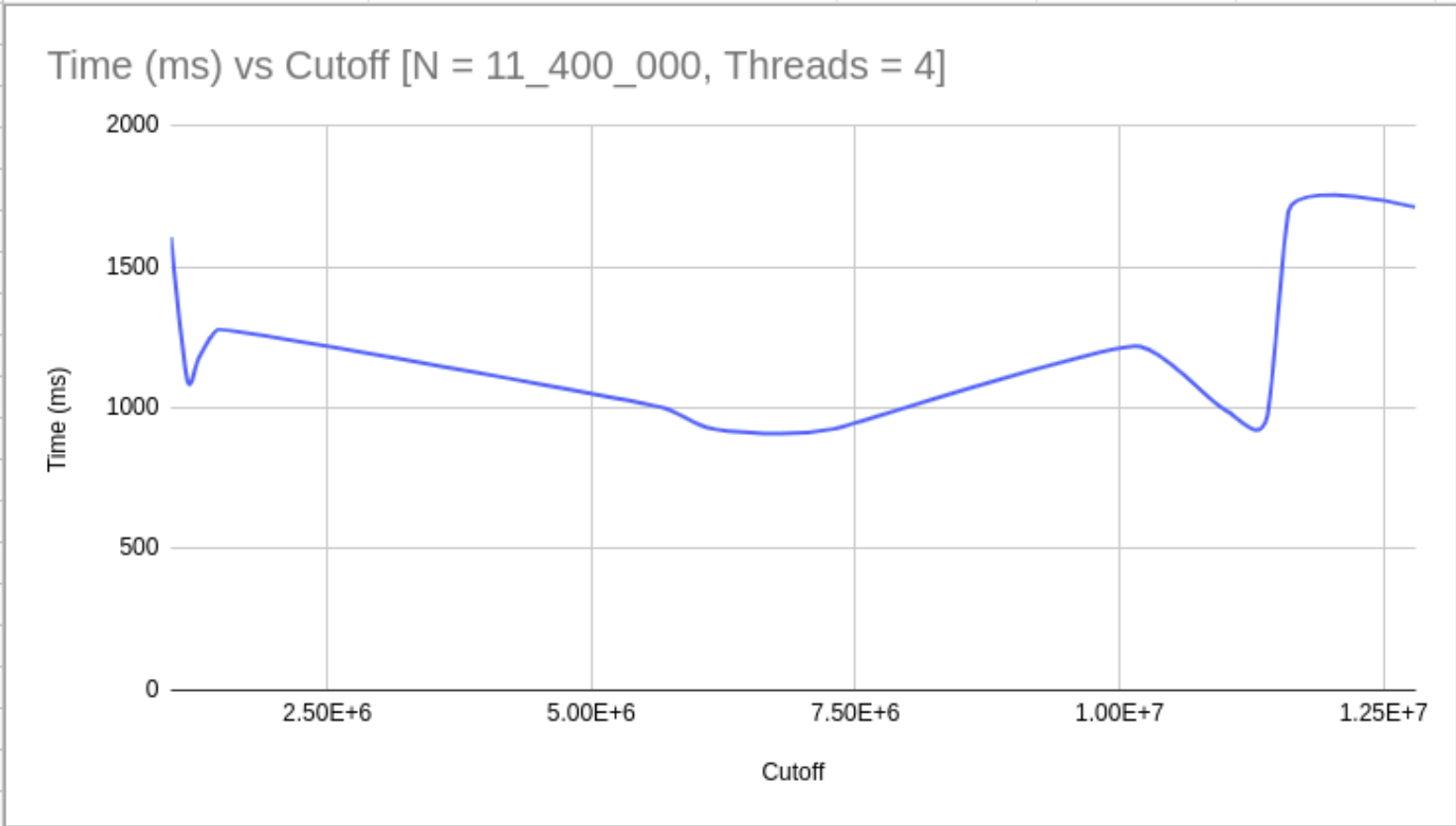
```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 4
ArraySize: 11400000 Cutoff : 5100000 Time:1372ms
ArraySize: 11400000 Cutoff : 5200000 Time:1025ms
ArraySize: 11400000 Cutoff : 5300000 Time:1052ms
ArraySize: 11400000 Cutoff : 5400000 Time:1017ms
ArraySize: 11400000 Cutoff : 5500000 Time:957ms
ArraySize: 11400000 Cutoff : 5600000 Time:977ms
ArraySize: 11400000 Cutoff : 5700000 Time:998ms
ArraySize: 11400000 Cutoff : 5800000 Time:933ms
ArraySize: 11400000 Cutoff : 5900000 Time:910ms
ArraySize: 11400000 Cutoff : 6000000 Time:911ms
ArraySize: 11400000 Cutoff : 6100000 Time:929ms
ArraySize: 11400000 Cutoff : 6200000 Time:953ms
ArraySize: 11400000 Cutoff : 6300000 Time:965ms
ArraySize: 11400000 Cutoff : 6400000 Time:932ms
ArraySize: 11400000 Cutoff : 6500000 Time:915ms
ArraySize: 11400000 Cutoff : 6600000 Time:955ms
ArraySize: 11400000 Cutoff : 6700000 Time:926ms
ArraySize: 11400000 Cutoff : 6800000 Time:908ms
ArraySize: 11400000 Cutoff : 6900000 Time:911ms
ArraySize: 11400000 Cutoff : 7000000 Time:920ms
ArraySize: 11400000 Cutoff : 7100000 Time:918ms
ArraySize: 11400000 Cutoff : 7200000 Time:911ms
ArraySize: 11400000 Cutoff : 7300000 Time:925ms
```

c) Cutoff towards the end of length

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 4
ArraySize: 11400000 Cutoff : 10200000 Time:1217ms
ArraySize: 11400000 Cutoff : 10400000 Time:1034ms
ArraySize: 11400000 Cutoff : 10600000 Time:1014ms
ArraySize: 11400000 Cutoff : 10800000 Time:1026ms
ArraySize: 11400000 Cutoff : 11000000 Time:992ms
ArraySize: 11400000 Cutoff : 11200000 Time:994ms
ArraySize: 11400000 Cutoff : 11400000 Time:974ms
ArraySize: 11400000 Cutoff : 11600000 Time:1696ms
ArraySize: 11400000 Cutoff : 11800000 Time:1697ms
ArraySize: 11400000 Cutoff : 12000000 Time:1714ms
ArraySize: 11400000 Cutoff : 12200000 Time:1698ms
ArraySize: 11400000 Cutoff : 12400000 Time:1701ms
ArraySize: 11400000 Cutoff : 12600000 Time:1703ms
ArraySize: 11400000 Cutoff : 12800000 Time:1711ms
ArraySize: 11400000 Cutoff : 13000000 Time:1686ms
ArraySize: 11400000 Cutoff : 13200000 Time:1700ms
ArraySize: 11400000 Cutoff : 13400000 Time:1693ms
ArraySize: 11400000 Cutoff : 13600000 Time:1697ms
ArraySize: 11400000 Cutoff : 13800000 Time:1696ms
ArraySize: 11400000 Cutoff : 14000000 Time:1694ms
ArraySize: 11400000 Cutoff : 14200000 Time:1701ms
ArraySize: 11400000 Cutoff : 14400000 Time:1700ms
ArraySize: 11400000 Cutoff : 14600000 Time:1699ms
```


Tabulation:

A	B	C	D	E	
Cutoff	Time (ms)				
1020000	1605				
1180000	1092				
1280000	1173				
1460000	1276				
5700000	998	Halfway mark			
6100000	929				
6800000	908				
7300000	925				
10200000	1217				
11000000	992				
11400000	974				
11600000	1696				
12800000	1711				

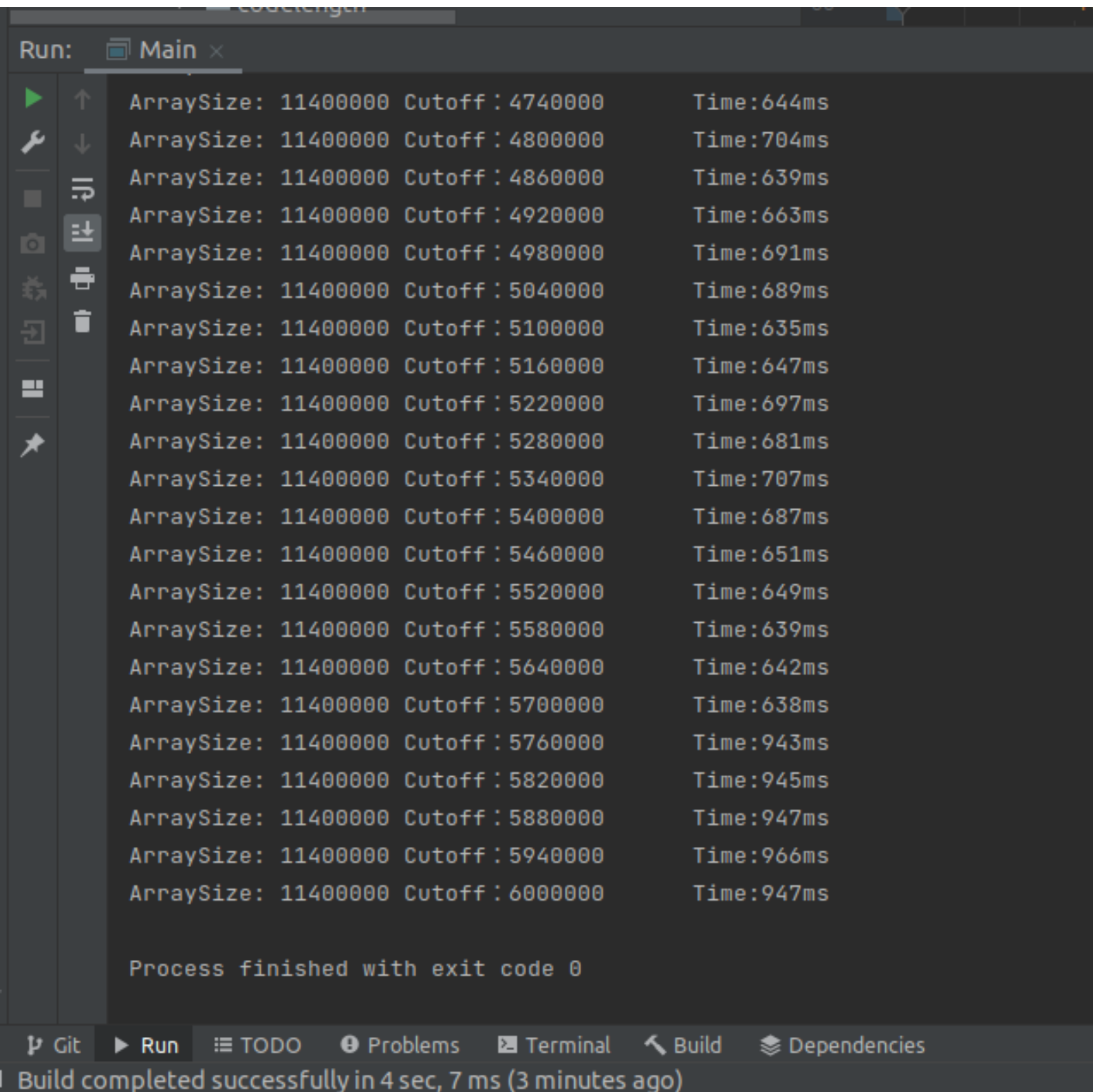


For number of threads = 8

a) Cutoff towards the start of length

Run: Main x		
▶	↑	ArraySize: 11400000 Cutoff : 2320000 Time:807ms
⚙	↓	ArraySize: 11400000 Cutoff : 2360000 Time:940ms
■	↕	ArraySize: 11400000 Cutoff : 2400000 Time:929ms
📷	⬇	ArraySize: 11400000 Cutoff : 2440000 Time:1000ms
🔍	🖨	ArraySize: 11400000 Cutoff : 2480000 Time:890ms
⚙	🗑	ArraySize: 11400000 Cutoff : 2520000 Time:854ms
📄		ArraySize: 11400000 Cutoff : 2560000 Time:809ms
📦		ArraySize: 11400000 Cutoff : 2600000 Time:900ms
📌		ArraySize: 11400000 Cutoff : 2640000 Time:812ms
		ArraySize: 11400000 Cutoff : 2680000 Time:810ms
		ArraySize: 11400000 Cutoff : 2720000 Time:859ms
		ArraySize: 11400000 Cutoff : 2760000 Time:912ms
		ArraySize: 11400000 Cutoff : 2800000 Time:959ms
		ArraySize: 11400000 Cutoff : 2840000 Time:816ms
		ArraySize: 11400000 Cutoff : 2880000 Time:609ms
		ArraySize: 11400000 Cutoff : 2920000 Time:616ms
		ArraySize: 11400000 Cutoff : 2960000 Time:639ms
		ArraySize: 11400000 Cutoff : 3000000 Time:632ms
		ArraySize: 11400000 Cutoff : 3040000 Time:665ms
		ArraySize: 11400000 Cutoff : 3080000 Time:618ms
		ArraySize: 11400000 Cutoff : 3120000 Time:631ms
		ArraySize: 11400000 Cutoff : 3160000 Time:608ms
		ArraySize: 11400000 Cutoff : 3200000 Time:680ms
		ArraySize: 11400000 Cutoff : 3240000 Time:665ms
		ArraySize: 11400000 Cutoff : 3280000 Time:615ms

b) Cutoff towards half of length



```
Run: Main x
ArraySize: 11400000 Cutoff : 4740000 Time:644ms
ArraySize: 11400000 Cutoff : 4800000 Time:704ms
ArraySize: 11400000 Cutoff : 4860000 Time:639ms
ArraySize: 11400000 Cutoff : 4920000 Time:663ms
ArraySize: 11400000 Cutoff : 4980000 Time:691ms
ArraySize: 11400000 Cutoff : 5040000 Time:689ms
ArraySize: 11400000 Cutoff : 5100000 Time:635ms
ArraySize: 11400000 Cutoff : 5160000 Time:647ms
ArraySize: 11400000 Cutoff : 5220000 Time:697ms
ArraySize: 11400000 Cutoff : 5280000 Time:681ms
ArraySize: 11400000 Cutoff : 5340000 Time:707ms
ArraySize: 11400000 Cutoff : 5400000 Time:687ms
ArraySize: 11400000 Cutoff : 5460000 Time:651ms
ArraySize: 11400000 Cutoff : 5520000 Time:649ms
ArraySize: 11400000 Cutoff : 5580000 Time:639ms
ArraySize: 11400000 Cutoff : 5640000 Time:642ms
ArraySize: 11400000 Cutoff : 5700000 Time:638ms
ArraySize: 11400000 Cutoff : 5760000 Time:943ms
ArraySize: 11400000 Cutoff : 5820000 Time:945ms
ArraySize: 11400000 Cutoff : 5880000 Time:947ms
ArraySize: 11400000 Cutoff : 5940000 Time:966ms
ArraySize: 11400000 Cutoff : 6000000 Time:947ms

Process finished with exit code 0

Git Run TODO Problems Terminal Build Dependencies
Build completed successfully in 4 sec, 7 ms (3 minutes ago)
```

c) Cutoff towards end of length

```
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
```

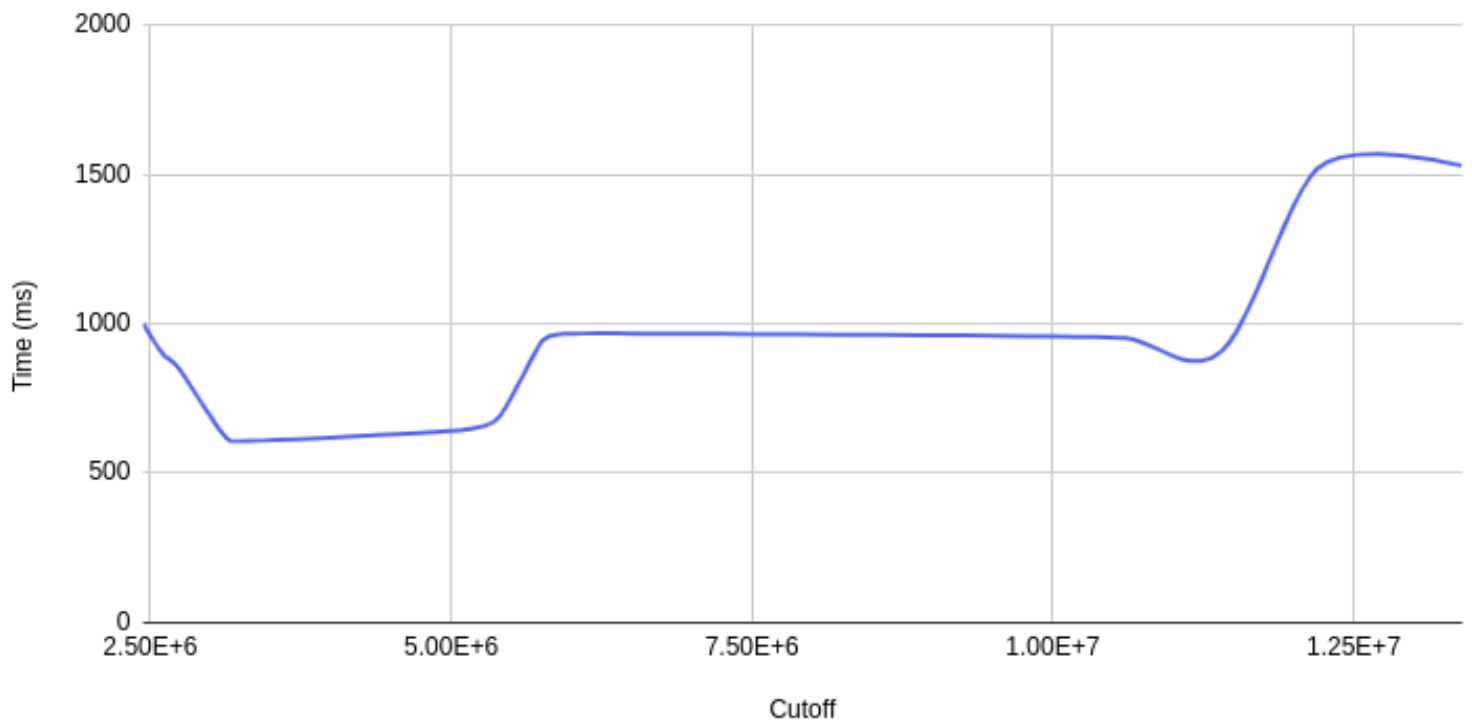
```
Thread count 8
```

ArraySize: 11400000	Cutoff : 10200000	Time: 1265ms
ArraySize: 11400000	Cutoff : 10400000	Time: 948ms
ArraySize: 11400000	Cutoff : 10600000	Time: 952ms
ArraySize: 11400000	Cutoff : 10800000	Time: 943ms
ArraySize: 11400000	Cutoff : 11000000	Time: 915ms
ArraySize: 11400000	Cutoff : 11200000	Time: 929ms
ArraySize: 11400000	Cutoff : 11400000	Time: 907ms
ArraySize: 11400000	Cutoff : 11600000	Time: 1514ms
ArraySize: 11400000	Cutoff : 11800000	Time: 1525ms
ArraySize: 11400000	Cutoff : 12000000	Time: 1518ms
ArraySize: 11400000	Cutoff : 12200000	Time: 1519ms
ArraySize: 11400000	Cutoff : 12400000	Time: 1512ms
ArraySize: 11400000	Cutoff : 12600000	Time: 1525ms
ArraySize: 11400000	Cutoff : 12800000	Time: 1524ms
ArraySize: 11400000	Cutoff : 13000000	Time: 1509ms
ArraySize: 11400000	Cutoff : 13200000	Time: 1519ms
ArraySize: 11400000	Cutoff : 13400000	Time: 1529ms
ArraySize: 11400000	Cutoff : 13600000	Time: 1521ms
ArraySize: 11400000	Cutoff : 13800000	Time: 1521ms
ArraySize: 11400000	Cutoff : 14000000	Time: 1521ms
ArraySize: 11400000	Cutoff : 14200000	Time: 1518ms
ArraySize: 11400000	Cutoff : 14400000	Time: 1518ms
ArraySize: 11400000	Cutoff : 14600000	Time: 1524ms

Tabulation:

A	B	C	D	E	
Cutoff	Time (ms)				
2440000	1000				
2600000	900				
2720000	859				
3040000	665				
3160000	608				
5160000	647				
5400000	687	Halfway mark			
5760000	943				
5940000	966				
10600000	952				
11400000	907				
12200000	1519				
13400000	1529				

Time (ms) vs Cutoff [N = 11_400_000, Threads = 8]



For number of threads = 16

a) Cutoff near start of length

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 16
ArraySize: 11400000 Cutoff : 1275000 Time:1146ms
ArraySize: 11400000 Cutoff : 1300000 Time:813ms
ArraySize: 11400000 Cutoff : 1325000 Time:730ms
ArraySize: 11400000 Cutoff : 1350000 Time:768ms
ArraySize: 11400000 Cutoff : 1375000 Time:677ms
ArraySize: 11400000 Cutoff : 1400000 Time:663ms
ArraySize: 11400000 Cutoff : 1425000 Time:704ms
ArraySize: 11400000 Cutoff : 1450000 Time:517ms
ArraySize: 11400000 Cutoff : 1475000 Time:567ms
ArraySize: 11400000 Cutoff : 1500000 Time:562ms
ArraySize: 11400000 Cutoff : 1525000 Time:514ms
ArraySize: 11400000 Cutoff : 1550000 Time:569ms
ArraySize: 11400000 Cutoff : 1575000 Time:513ms
ArraySize: 11400000 Cutoff : 1600000 Time:524ms
ArraySize: 11400000 Cutoff : 1625000 Time:550ms
ArraySize: 11400000 Cutoff : 1650000 Time:590ms
ArraySize: 11400000 Cutoff : 1675000 Time:523ms
ArraySize: 11400000 Cutoff : 1700000 Time:517ms
ArraySize: 11400000 Cutoff : 1725000 Time:566ms
ArraySize: 11400000 Cutoff : 1750000 Time:537ms
ArraySize: 11400000 Cutoff : 1775000 Time:529ms
ArraySize: 11400000 Cutoff : 1800000 Time:523ms
ArraySize: 11400000 Cutoff : 1825000 Time:559ms
```

b) Cutoff towards half of length

```
Run: Main x
↑
↓
ArraySize: 11400000 Cutoff : 4740000 Time:639ms
ArraySize: 11400000 Cutoff : 4800000 Time:671ms
ArraySize: 11400000 Cutoff : 4860000 Time:640ms
ArraySize: 11400000 Cutoff : 4920000 Time:665ms
ArraySize: 11400000 Cutoff : 4980000 Time:660ms
ArraySize: 11400000 Cutoff : 5040000 Time:643ms
ArraySize: 11400000 Cutoff : 5100000 Time:668ms
ArraySize: 11400000 Cutoff : 5160000 Time:663ms
ArraySize: 11400000 Cutoff : 5220000 Time:685ms
ArraySize: 11400000 Cutoff : 5280000 Time:676ms
ArraySize: 11400000 Cutoff : 5340000 Time:685ms
ArraySize: 11400000 Cutoff : 5400000 Time:636ms
ArraySize: 11400000 Cutoff : 5460000 Time:635ms
ArraySize: 11400000 Cutoff : 5520000 Time:640ms
ArraySize: 11400000 Cutoff : 5580000 Time:643ms
ArraySize: 11400000 Cutoff : 5640000 Time:664ms
ArraySize: 11400000 Cutoff : 5700000 Time:667ms
ArraySize: 11400000 Cutoff : 5760000 Time:954ms
ArraySize: 11400000 Cutoff : 5820000 Time:961ms
ArraySize: 11400000 Cutoff : 5880000 Time:940ms
ArraySize: 11400000 Cutoff : 5940000 Time:944ms
ArraySize: 11400000 Cutoff : 6000000 Time:956ms

Process finished with exit code 0
```

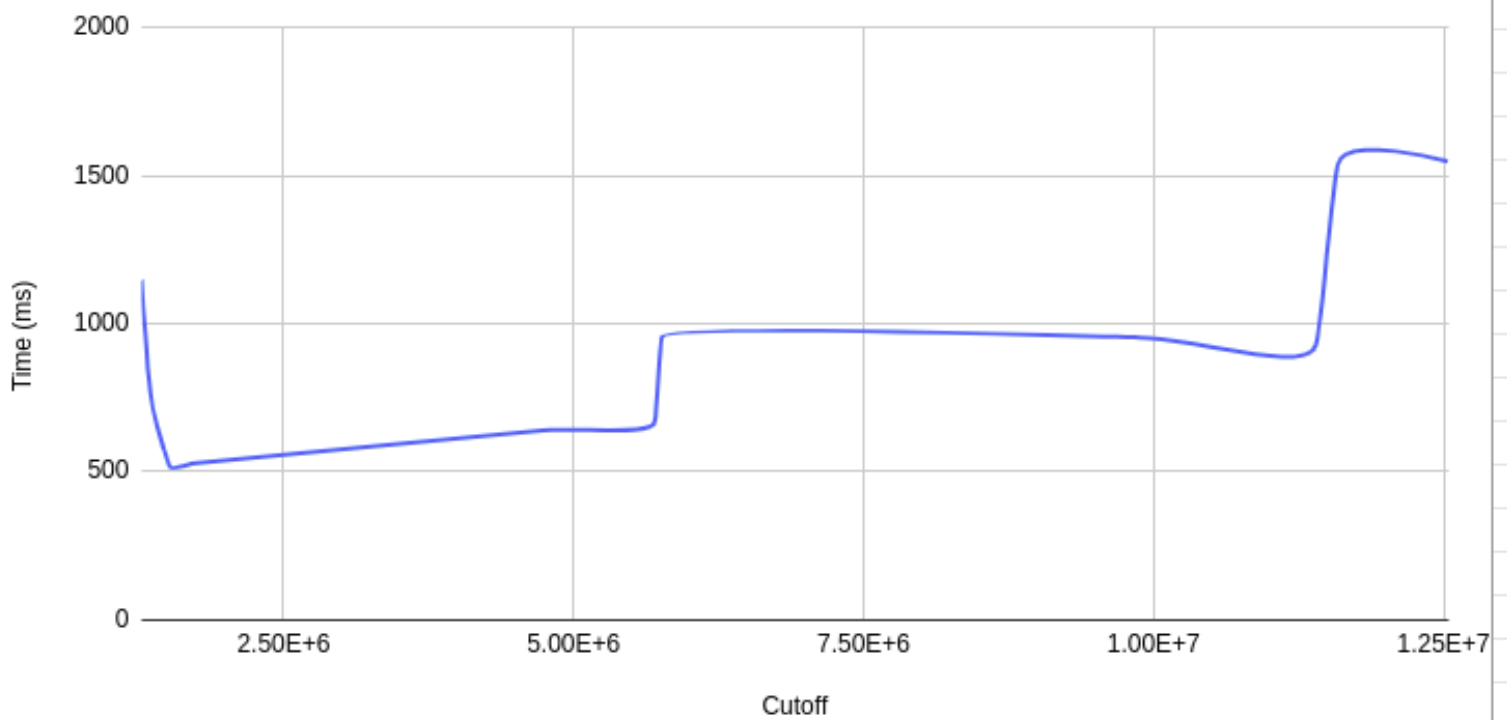
c) Cutoff towards end of length

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 16
ArraySize: 11400000 Cutoff: 9690000 Time: 1154ms
ArraySize: 11400000 Cutoff: 9880000 Time: 953ms
ArraySize: 11400000 Cutoff: 10070000 Time: 921ms
ArraySize: 11400000 Cutoff: 10260000 Time: 922ms
ArraySize: 11400000 Cutoff: 10450000 Time: 916ms
ArraySize: 11400000 Cutoff: 10640000 Time: 905ms
ArraySize: 11400000 Cutoff: 10830000 Time: 928ms
ArraySize: 11400000 Cutoff: 11020000 Time: 909ms
ArraySize: 11400000 Cutoff: 11210000 Time: 920ms
ArraySize: 11400000 Cutoff: 11400000 Time: 927ms
ArraySize: 11400000 Cutoff: 11590000 Time: 1539ms
ArraySize: 11400000 Cutoff: 11780000 Time: 1535ms
ArraySize: 11400000 Cutoff: 11970000 Time: 1536ms
ArraySize: 11400000 Cutoff: 12160000 Time: 1520ms
ArraySize: 11400000 Cutoff: 12350000 Time: 1523ms
ArraySize: 11400000 Cutoff: 12540000 Time: 1547ms
ArraySize: 11400000 Cutoff: 12730000 Time: 1530ms
ArraySize: 11400000 Cutoff: 12920000 Time: 1531ms
ArraySize: 11400000 Cutoff: 13110000 Time: 1542ms
ArraySize: 11400000 Cutoff: 13300000 Time: 1536ms
ArraySize: 11400000 Cutoff: 13490000 Time: 1540ms
ArraySize: 11400000 Cutoff: 13680000 Time: 1518ms
ArraySize: 11400000 Cutoff: 13870000 Time: 1533ms
```


Tabulation:

A	B	C	D	E	
Cutoff	Time (ms)				
1275000	1146				
1350000	768				
1475000	567				
1525000	514				
1750000	529				
4740000	639				
5700000	667	Halfway mark			
5760000	954				
9880000	953				
11400000	927				
11590000	1539				
12540000	1547				

Time (ms) vs Cutoff [N = 11_400_000, Threads = 8]



Conclusions:

1) Parallel sort is worthwhile only for larger sized arrays as opposed to smaller sized array which sort quicker using the system sort as seen below:

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 4
ArraySize: 50000 Cutoff : 2550      Time:131ms
ArraySize: 50000 Cutoff : 2600      Time:49ms
ArraySize: 50000 Cutoff : 2650      Time:32ms
ArraySize: 50000 Cutoff : 2700      Time:17ms
ArraySize: 50000 Cutoff : 2750      Time:30ms
ArraySize: 50000 Cutoff : 2800      Time:23ms
ArraySize: 50000 Cutoff : 2850      Time:16ms
ArraySize: 50000 Cutoff : 2900      Time:9ms
ArraySize: 50000 Cutoff : 2950      Time:24ms
ArraySize: 50000 Cutoff : 3000      Time:7ms
ArraySize: 50000 Cutoff : 3050      Time:9ms
ArraySize: 50000 Cutoff : 3100      Time:8ms
ArraySize: 50000 Cutoff : 3150      Time:5ms
ArraySize: 50000 Cutoff : 3200      Time:5ms
ArraySize: 50000 Cutoff : 3250      Time:5ms
ArraySize: 50000 Cutoff : 3300      Time:6ms
ArraySize: 50000 Cutoff : 3350      Time:14ms
ArraySize: 50000 Cutoff : 3400      Time:6ms
ArraySize: 50000 Cutoff : 3450      Time:6ms
ArraySize: 50000 Cutoff : 3500      Time:6ms
ArraySize: 50000 Cutoff : 3550      Time:6ms
ArraySize: 50000 Cutoff : 3600      Time:5ms
ArraySize: 50000 Cutoff : 3650      Time:5ms
```

As seen above, post cutoff (System sort condition), the time taken to sort the array is quicker using the system sort

```
Run: Main x
/usr/lib/jvm/java-1.8.0-openjdk-amd64/bin/java ...
Thread count 4
ArraySize: 11400000 Cutoff : 10200000 Time:1217ms
ArraySize: 11400000 Cutoff : 10400000 Time:1034ms
ArraySize: 11400000 Cutoff : 10600000 Time:1014ms
ArraySize: 11400000 Cutoff : 10800000 Time:1026ms
ArraySize: 11400000 Cutoff : 11000000 Time:992ms
ArraySize: 11400000 Cutoff : 11200000 Time:994ms
ArraySize: 11400000 Cutoff : 11400000 Time:974ms
ArraySize: 11400000 Cutoff : 11600000 Time:1696ms
ArraySize: 11400000 Cutoff : 11800000 Time:1697ms
ArraySize: 11400000 Cutoff : 12000000 Time:1714ms
ArraySize: 11400000 Cutoff : 12200000 Time:1698ms
ArraySize: 11400000 Cutoff : 12400000 Time:1701ms
ArraySize: 11400000 Cutoff : 12600000 Time:1703ms
ArraySize: 11400000 Cutoff : 12800000 Time:1711ms
ArraySize: 11400000 Cutoff : 13000000 Time:1686ms
ArraySize: 11400000 Cutoff : 13200000 Time:1700ms
ArraySize: 11400000 Cutoff : 13400000 Time:1693ms
ArraySize: 11400000 Cutoff : 13600000 Time:1697ms
ArraySize: 11400000 Cutoff : 13800000 Time:1696ms
ArraySize: 11400000 Cutoff : 14000000 Time:1694ms
ArraySize: 11400000 Cutoff : 14200000 Time:1701ms
ArraySize: 11400000 Cutoff : 14400000 Time:1700ms
ArraySize: 11400000 Cutoff : 14600000 Time:1699ms
```

As seen above, post cutoff value (System sort condition) takes longer than the parallel sort technique for a larger array

2) Using number of threads as 2, 4 and above 16 (8 to 16 being the sweet spot) did not make the sorting more efficient and this could be as a result of threading thresholds and presence of overheads based on system to system but as seen on the screenshots, using number of threads = 2 is not the best optimization that is available.

3) Using thread numbers as either 8 or 16 or any int value in between has shown to have the best results.

4) (Array size used (N) = 11400000, Threads = 8) In the case of threads = 8, it is noticed that the time required to parallel sort is decreased and is at its best when the **cutoff is between $\sim(N/4)$ and $\sim(N/2)$ and after $N/2$ cutoff is reached, there is a spike in time required to sort and the sorting time starts to increase. Note: Sometimes the lower limit is below $\sim N/4$ too.**

5) (Array size used (N) 11400000, Threads = 16) In the case of threads = 16, the pattern of times for parallel sort is similar to that of times obtained when Thread number = 8. However, the lower times start to appear in the cutoff range very slightly earlier. The **cutoff is between $\sim(N/4)$ and $\sim(N/2)$ and after the $N/2$ cutoff is reached, there is a spike in time required to sort and the sorting time starts to increase. Note: Sometimes the lower limit is below $\sim N/4$ too.**

6) **The optimal cutoffs vary according to the variation of array sizes and hence occurs only in context of a given array size but the general trend being observed is that they lie somewhere between $\sim N/4$ s to $\sim N/2$ and post $N/2$, the time required to parallel sort starts to increase.**

7) **The optimal number of threads also depends on the number of cores available** in the system processor but a general trend is between **8 to 16** beyond which the time taken to perform the sort operations is higher.