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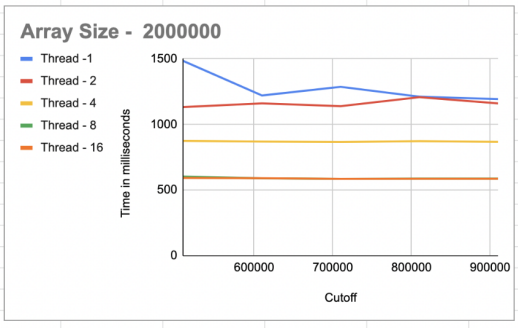
Program Structures & Algorithms
Fall 2021
Assignment 5

1. **Tasks Performed in the Assignment :**
    a. Understood and Implemented the ForkJoinPool to manipulate the number of threads
    b. Modified the Main.java file to initialize different array size, cutoff, and thread values
    c. Plotted the excel graph for Time taken to perform sort vs Number of Threads for different array sizes and cutoff values

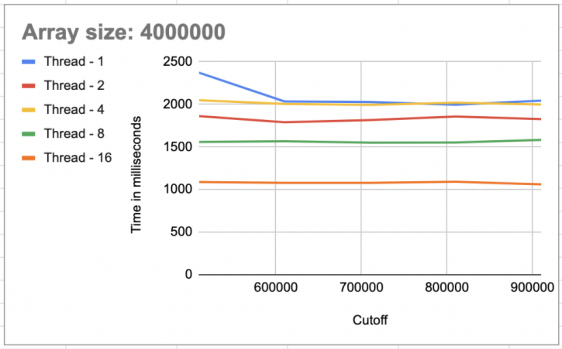
2. **Relationship conclusion:**
    a. The system used for this experiment is a Macbook with M1 chip and 8 core CPU.
    b. We can run 2 threads per core in parallel so at max 16 threads can be utilized
    c. When array size is between 2-4 Million, it can be seen from the graphs that single threaded applications perform poor than multi-threaded applications. When we increase the number of threads, the works load is divided and better performance is achieved
    d. However, increasing the number of threads does not always yield better results. For example - when increase the # of threads to 16 for array size of 1.2 Billion, the application performance degrades and it performs worse than the single threaded application
    e. So the ideal number of threads as per my system would be 8 and the cutoff value would be between 650k-750k

Array size: 2000000					
Cutoff	Thread - 1	Thread -2	Thread - 4	Thread - 8	Thread - 16
510000	1484	1133	875	603	592
610000	1221	1161	870	589	590
710000	1287	1139	867	586	586
810000	1212	1208	873	588	587
910000	1193	1161	868	588	587



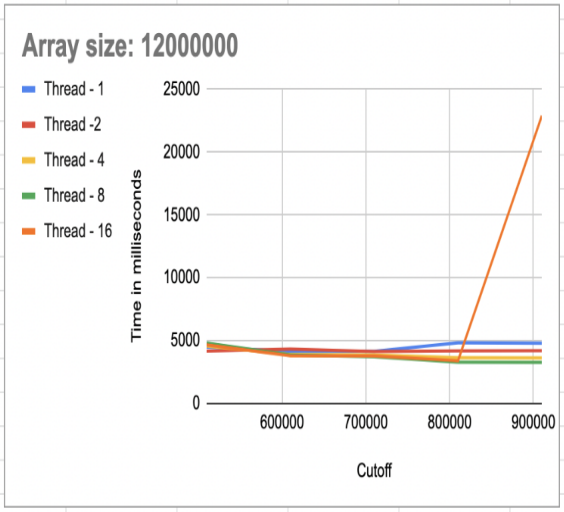
Array size: 4000000

Cutoff	Thread - 1	Thread -2	Thread - 4	Thread - 8	Thread - 16
510000	2372	1862	2049	1559	1088
610000	2034	1790	2005	1566	1078
710000	2027	1815	1993	1550	1079
810000	1995	1857	2020	1552	1092
910000	2043	1827	1999	1583	1061



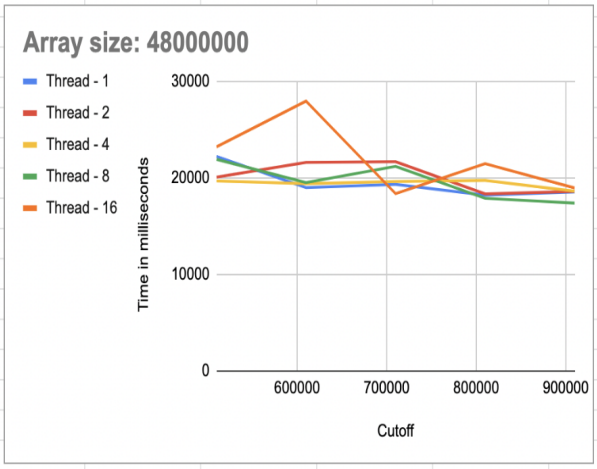
Array size: 12000000

Cutoff	Thread - 1	Thread -2	Thread - 4	Thread - 8	Thread - 16
510000	4500	4172	4580	4818	4673
610000	4147	4327	3894	3873	3806
710000	4153	4148	3874	3725	3791
810000	4838	4191	3637	3284	3405
910000	4799	4213	3630	3270	22881



Array size: 48000000

Cutoff	Thread - 1	Thread -2	Thread - 4	Thread - 8	Thread - 16
510000	22228	20064	19681	21919	23216
610000	18992	21593	19395	19503	27960
710000	19313	21673	19626	21192	18355
810000	18200	18328	19725	17872	21463
910000	18534	18598	18614	17370	18949



3. Evidence to support conclusion

```
/Users/riddhibhatti/Library/Java/JavaVirtualMachines/openjdk-16.0.2/Co
Array Size: 2000000
#threads 1 cutoff: 510000 1581 ms
#threads 1 cutoff: 610000 1261 ms
#threads 1 cutoff: 710000 1222 ms
#threads 1 cutoff: 810000 1191 ms
#threads 1 cutoff: 910000 1176 ms
#threads 2 cutoff: 510000 1145 ms
#threads 2 cutoff: 610000 1135 ms
#threads 2 cutoff: 710000 1120 ms
#threads 2 cutoff: 810000 1121 ms
#threads 2 cutoff: 910000 1115 ms
#threads 4 cutoff: 510000 859 ms
#threads 4 cutoff: 610000 864 ms
#threads 4 cutoff: 710000 859 ms
#threads 4 cutoff: 810000 857 ms
#threads 4 cutoff: 910000 852 ms
#threads 8 cutoff: 510000 589 ms
#threads 8 cutoff: 610000 588 ms
#threads 8 cutoff: 710000 580 ms
#threads 8 cutoff: 810000 578 ms
#threads 8 cutoff: 910000 579 ms
#threads 16 cutoff: 510000 583 ms
#threads 16 cutoff: 610000 581 ms
#threads 16 cutoff: 710000 578 ms
#threads 16 cutoff: 810000 579 ms
#threads 16 cutoff: 910000 580 ms
Array Size: 4000000
#threads 1 cutoff: 510000 2372 ms
#threads 1 cutoff: 610000 2034 ms
#threads 1 cutoff: 710000 2027 ms
#threads 1 cutoff: 810000 1995 ms
#threads 1 cutoff: 910000 2043 ms
#threads 2 cutoff: 510000 1862 ms
#threads 2 cutoff: 610000 1790 ms
```

```
Array Size: 4000000
#threads 1 cutoff: 510000 2372 ms
#threads 1 cutoff: 610000 2034 ms
#threads 1 cutoff: 710000 2027 ms
#threads 1 cutoff: 810000 1995 ms
#threads 1 cutoff: 910000 2043 ms
#threads 2 cutoff: 510000 1862 ms
#threads 2 cutoff: 610000 1790 ms
#threads 2 cutoff: 710000 1815 ms
#threads 2 cutoff: 810000 1857 ms
#threads 2 cutoff: 910000 1827 ms
#threads 4 cutoff: 510000 2049 ms
#threads 4 cutoff: 610000 2005 ms
#threads 4 cutoff: 710000 1993 ms
#threads 4 cutoff: 810000 2020 ms
#threads 4 cutoff: 910000 1999 ms
#threads 8 cutoff: 510000 1559 ms
#threads 8 cutoff: 610000 1566 ms
#threads 8 cutoff: 710000 1550 ms
#threads 8 cutoff: 810000 1552 ms
#threads 8 cutoff: 910000 1583 ms
#threads 16 cutoff: 510000 1088 ms
#threads 16 cutoff: 610000 1078 ms
#threads 16 cutoff: 710000 1079 ms
#threads 16 cutoff: 810000 1092 ms
#threads 16 cutoff: 910000 1061 ms
Array Size: 12000000
#threads 1 cutoff: 510000 4500 ms
#threads 1 cutoff: 610000 4147 ms
#threads 1 cutoff: 710000 4153 ms
#threads 1 cutoff: 810000 4838 ms
#threads 1 cutoff: 910000 4799 ms
#threads 2 cutoff: 510000 4172 ms
#threads 2 cutoff: 610000 4327 ms
```

```
#threads 16 cutoff: 910000 1001 ms
Array Size: 12000000
#threads 1 cutoff: 510000 4500 ms
#threads 1 cutoff: 610000 4147 ms
#threads 1 cutoff: 710000 4153 ms
#threads 1 cutoff: 810000 4838 ms
#threads 1 cutoff: 910000 4799 ms
#threads 2 cutoff: 510000 4172 ms
#threads 2 cutoff: 610000 4327 ms
#threads 2 cutoff: 710000 4148 ms
#threads 2 cutoff: 810000 4191 ms
#threads 2 cutoff: 910000 4213 ms
#threads 4 cutoff: 510000 4580 ms
#threads 4 cutoff: 610000 3894 ms
#threads 4 cutoff: 710000 3874 ms
#threads 4 cutoff: 810000 3637 ms
#threads 4 cutoff: 910000 3630 ms
#threads 8 cutoff: 510000 4818 ms
#threads 8 cutoff: 610000 3873 ms
#threads 8 cutoff: 710000 3725 ms
#threads 8 cutoff: 810000 3284 ms
#threads 8 cutoff: 910000 3270 ms
#threads 16 cutoff: 510000 4673 ms
#threads 16 cutoff: 610000 3806 ms
#threads 16 cutoff: 710000 3791 ms
#threads 16 cutoff: 810000 3405 ms
#threads 16 cutoff: 910000 22881 ms
Array Size: 48000000
#threads 1 cutoff: 510000 22228 ms
#threads 1 cutoff: 610000 18992 ms
#threads 1 cutoff: 710000 19313 ms
#threads 1 cutoff: 810000 18200 ms
#threads 1 cutoff: 910000 18534 ms
#threads 2 cutoff: 510000 20064 ms
#threads 2 cutoff: 610000 21593 ms
```

```
#threads 16 cutoff: 910000 22881 ms
Array Size: 48000000
#threads 1 cutoff: 510000 22228 ms
#threads 1 cutoff: 610000 18992 ms
#threads 1 cutoff: 710000 19313 ms
#threads 1 cutoff: 810000 18200 ms
#threads 1 cutoff: 910000 18534 ms
#threads 2 cutoff: 510000 20064 ms
#threads 2 cutoff: 610000 21593 ms
#threads 2 cutoff: 710000 21673 ms
#threads 2 cutoff: 810000 18328 ms
#threads 2 cutoff: 910000 18598 ms
#threads 4 cutoff: 510000 19681 ms
#threads 4 cutoff: 610000 19395 ms
#threads 4 cutoff: 710000 19626 ms
#threads 4 cutoff: 810000 19725 ms
#threads 4 cutoff: 910000 18614 ms
#threads 8 cutoff: 510000 21919 ms
#threads 8 cutoff: 610000 19503 ms
#threads 8 cutoff: 710000 21192 ms
#threads 8 cutoff: 810000 17872 ms
#threads 8 cutoff: 910000 17370 ms
#threads 16 cutoff: 510000 23216 ms
#threads 16 cutoff: 610000 27960 ms
#threads 16 cutoff: 710000 18355 ms
#threads 16 cutoff: 810000 21463 ms
#threads 16 cutoff: 910000 18949 ms
```