

Program Structures & Algorithms

Spring 2022

Assignment No. 04 - Parallel Sorting

Name : Akshay Kumthi Matad

(NUID) : 002928833

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.

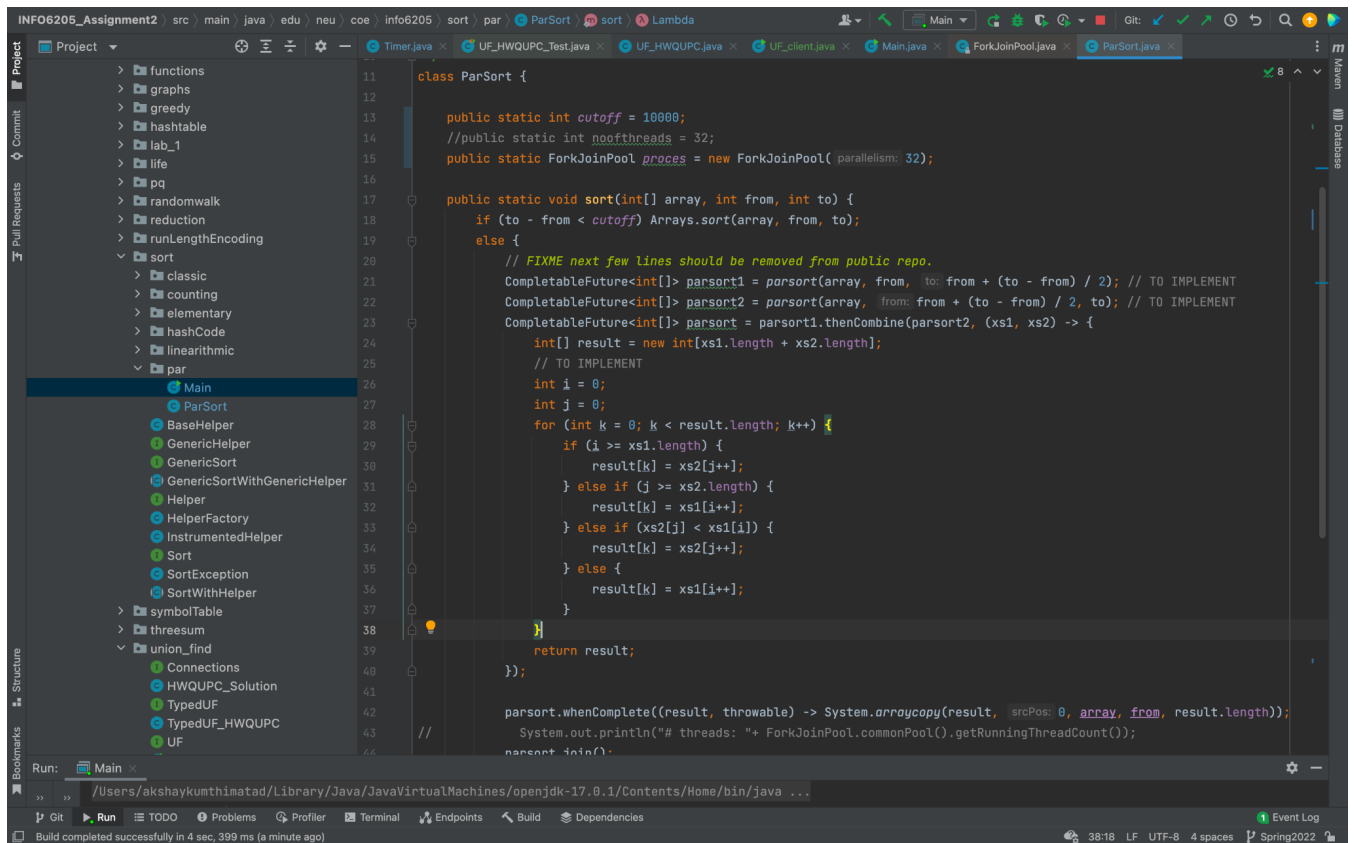
There is a *Main* class and the *ParSort* class in the *sort.par* package of the INFO6205 repository. The *Main* class can be used as is but the *ParSort* class needs to be implemented where you see "TODO..." [it turns out that these TODOs are already implemented].

Unless you have a good reason not to, you should just go along with the Java8-style future implementations provided for you in the class repository.

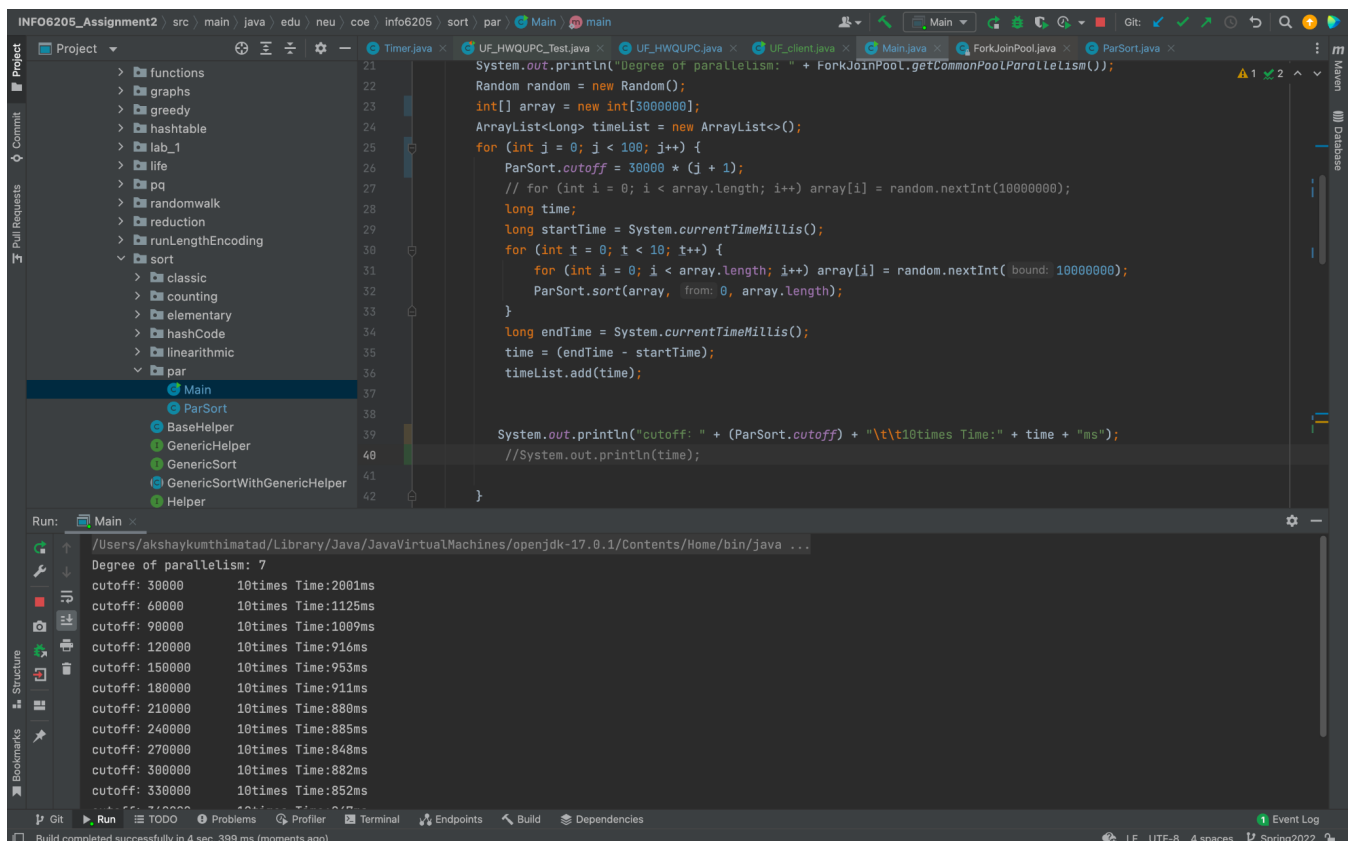
You must prepare a report that shows the results of your experiments and draws a conclusion (or more) about the efficacy of this method of parallelizing sort. Your experiments should involve sorting arrays of sufficient size for the parallel sort to make a difference. You should run with many different array sizes (they must be sufficiently large to make parallel sorting worthwhile, obviously) and different cutoff schemes.

OUTPUT SCREENSHOTS:

1) Changed ParSort.java to handle thread counts



2) Output of Main.java and changing the array sizes and cutoffs



Graphs and Evidence:

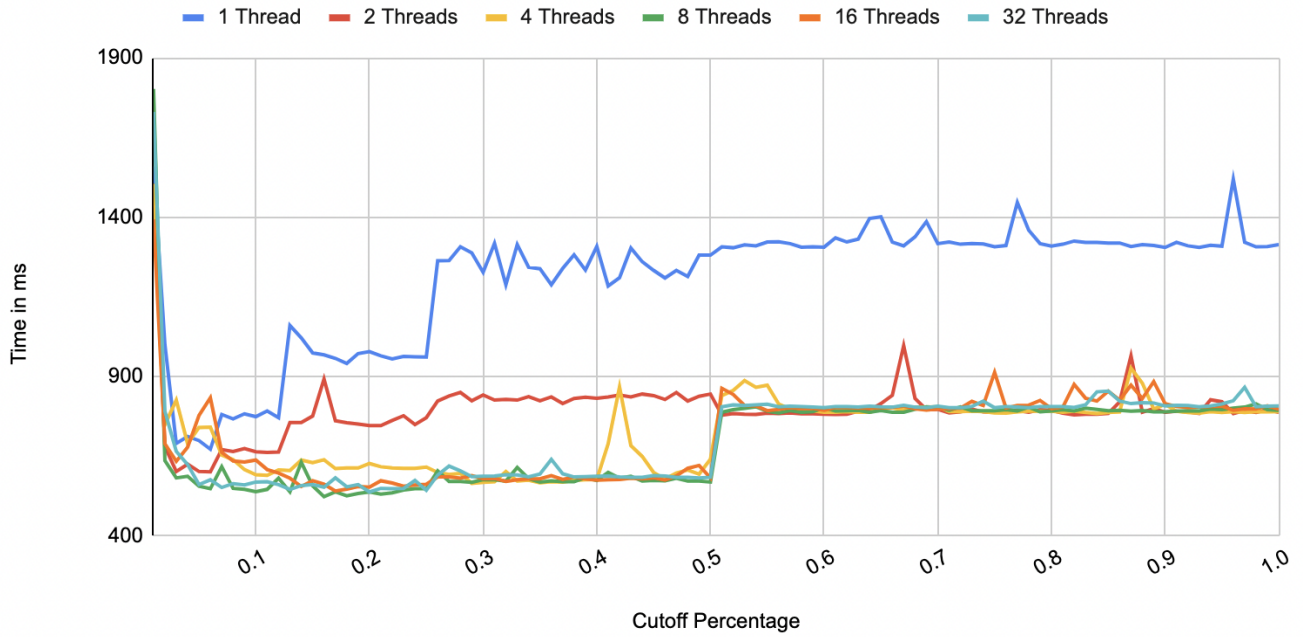
1) For Array size : 2,000,000

Cutoff	Cutoff percentage	1 Thread	2 Threads	4 Threads	8 Threads	16 Threads	32 Threads
20000	0.01	1559	1505	1504	1802	1393	1730
40000	0.02	1000	680	749	636	689	791
60000	0.03	690	602	826	582	634	665
80000	0.04	712	625	689	587	678	624
100000	0.05	699	602	740	556	778	561
120000	0.06	672	601	741	548	833	576
140000	0.07	781	671	654	617	662	552
160000	0.08	767	665	639	549	635	564
180000	0.09	783	674	608	546	632	560
200000	0.1	774	664	592	539	638	569
220000	0.11	792	662	590	546	608	570
240000	0.12	771	663	607	581	597	561
260000	0.13	1060	756	605	538	581	546
280000	0.14	1021	756	638	631	555	558
300000	0.15	974	776	630	557	573	561
320000	0.16	968	892	639	523	562	553
340000	0.17	957	761	611	538	541	582
360000	0.18	941	755	613	526	547	554
380000	0.19	972	751	613	533	555	561
400000	0.2	978	746	627	538	553	538
420000	0.21	965	746	617	531	573	549
440000	0.22	955	762	613	535	566	548
460000	0.23	963	777	612	544	556	549
480000	0.24	962	749	612	548	560	574
500000	0.25	961	771	616	548	562	543
520000	0.26	1263	823	599	604	585	591
540000	0.27	1264	839	593	571	585	619
560000	0.28	1307	850	596	571	581	604
580000	0.29	1288	824	565	568	589	586
600000	0.3	1227	842	568	577	579	587
620000	0.31	1318	826	570	576	580	588
640000	0.32	1188	828	602	572	571	592
660000	0.33	1314	826	572	615	576	591
680000	0.34	1243	837	575	580	579	585
700000	0.35	1238	824	567	569	579	594

720000	0.36	1188	836	570	573	589	640
740000	0.37	1239	815	569	570	577	595
760000	0.38	1282	831	574	570	585	585
780000	0.39	1234	835	576	583	579	586
800000	0.4	1308	832	577	574	575	587
820000	0.41	1184	836	689	599	576	588
840000	0.42	1210	842	867	581	577	585
860000	0.43	1303	836	683	587	581	584
880000	0.44	1260	845	649	572	579	584
900000	0.45	1233	840	599	574	582	589
920000	0.46	1209	828	578	573	575	588
940000	0.47	1233	850	597	581	588	584
960000	0.48	1214	823	607	572	612	584
980000	0.49	1281	838	594	572	621	582
1000000	0.5	1281	845	641	569	582	584
1020000	0.51	1307	779	840	788	863	805
1040000	0.52	1304	784	856	796	844	811
1060000	0.53	1313	782	887	800	809	809
1080000	0.54	1310	781	866	805	808	811
1100000	0.55	1322	785	873	791	793	813
1120000	0.56	1323	784	814	786	797	805
1140000	0.57	1317	786	798	793	802	807
1160000	0.58	1306	783	797	788	799	806
1180000	0.59	1307	783	792	790	800	804
1200000	0.6	1306	782	788	802	794	802
1220000	0.61	1335	781	788	792	803	806
1240000	0.62	1322	782	790	793	802	806
1260000	0.63	1331	791	788	794	801	804
1280000	0.64	1396	794	788	788	801	807
1300000	0.65	1401	815	798	793	802	805
1320000	0.66	1322	841	802	788	803	804
1340000	0.67	1310	997	795	788	807	810
1360000	0.68	1338	831	804	797	799	804
1380000	0.69	1386	796	804	805	795	802
1400000	0.7	1317	797	805	803	798	807
1420000	0.71	1322	786	790	794	799	802
1440000	0.72	1315	789	790	805	801	802
1460000	0.73	1317	798	791	793	822	806
1480000	0.74	1316	789	790	793	809	823
1500000	0.75	1307	788	786	793	913	802

1520000	0.76	1311	794	785	796	801	806
1540000	0.77	1446	793	789	792	809	804
1560000	0.78	1359	788	791	804	810	802
1580000	0.79	1317	796	791	789	825	806
1600000	0.8	1309	794	791	792	799	806
1620000	0.81	1315	785	788	796	804	806
1640000	0.82	1325	780	791	792	875	803
1660000	0.83	1321	782	787	801	832	811
1680000	0.84	1321	782	784	797	823	852
1700000	0.85	1319	784	787	793	854	854
1720000	0.86	1319	820	789	794	826	823
1740000	0.87	1308	965	926	791	873	815
1760000	0.88	1314	788	879	793	831	818
1780000	0.89	1311	799	798	789	884	817
1800000	0.9	1305	788	813	789	815	808
1820000	0.91	1321	791	791	791	806	810
1840000	0.92	1310	789	787	793	803	809
1860000	0.93	1305	784	785	792	804	805
1880000	0.94	1312	827	790	798	806	808
1900000	0.95	1309	821	787	796	807	814
1920000	0.96	1519	784	790	801	794	824
1940000	0.97	1321	793	787	804	799	866
1960000	0.98	1307	787	790	814	798	805
1980000	0.99	1308	796	789	796	808	807
2000000	1	1314	788	790	794	797	808

Cutoff vs time



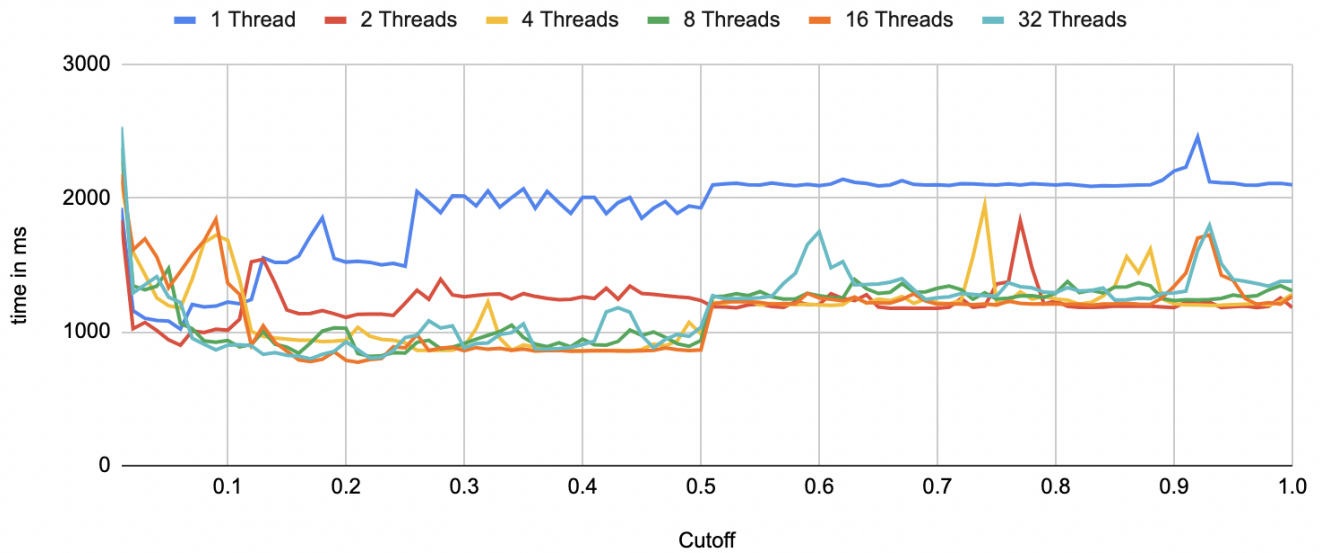
2) For array size = 3,000,000

Cutoff	Cutoff percentage	1 Thread	2 Threads	4 Threads	8 Threads	16 Threads	32 Threads
30000	0.01	1925	1833	2134	2373	2177	2530
60000	0.02	1157	1023	1595	1343	1612	1291
90000	0.03	1101	1070	1428	1314	1695	1351
120000	0.04	1085	1010	1253	1340	1560	1412
150000	0.05	1080	940	1195	1473	1329	1259
180000	0.06	1020	899	1177	1063	1450	1220
210000	0.07	1204	1006	1394	1023	1575	952
240000	0.08	1186	994	1665	932	1680	907
270000	0.09	1192	1019	1722	922	1840	864
300000	0.1	1222	1012	1683	935	1364	900
330000	0.11	1210	1094	1390	887	1280	903
360000	0.12	1241	1523	1002	906	898	896
390000	0.13	1552	1542	965	1003	1045	831
420000	0.14	1518	1363	954	907	920	844
450000	0.15	1518	1163	945	886	855	824
480000	0.16	1566	1136	937	839	790	818
510000	0.17	1716	1137	937	917	777	798
540000	0.18	1851	1159	927	1005	795	832
570000	0.19	1547	1134	931	1029	851	854
600000	0.2	1521	1108	937	1026	786	925
630000	0.21	1527	1131	1034	837	773	867
660000	0.22	1519	1132	968	816	792	803

690000	0.23	1500	1132	944	821	801	809
720000	0.24	1512	1122	937	844	888	861
750000	0.25	1490	1213	917	842	880	957
780000	0.26	2049	1310	861	921	978	974
810000	0.27	1970	1243	861	937	860	1082
840000	0.28	1890	1392	861	874	878	1028
870000	0.29	2015	1275	863	885	885	1044
900000	0.3	2014	1261	893	912	859	879
930000	0.31	1940	1271	1024	944	882	912
960000	0.32	2052	1279	1222	974	869	917
990000	0.33	1931	1283	953	1001	876	980
1020000	0.34	2002	1246	863	1049	861	993
1050000	0.35	2068	1285	901	958	872	1059
1080000	0.36	1923	1264	886	908	857	872
1110000	0.37	2049	1249	883	889	859	869
1140000	0.38	1964	1239	859	918	861	875
1170000	0.39	1885	1243	859	888	855	883
1200000	0.4	2004	1261	858	945	857	905
1230000	0.41	2004	1249	861	903	858	931
1260000	0.42	1883	1326	859	900	859	1148
1290000	0.43	1965	1244	861	928	857	1180
1320000	0.44	2004	1341	856	1013	856	1146
1350000	0.45	1848	1286	869	973	858	971
1380000	0.46	1924	1280	908	999	861	881
1410000	0.47	1973	1270	896	959	879	943
1440000	0.48	1885	1261	932	911	867	981
1470000	0.49	1940	1255	1071	892	860	967
1500000	0.5	1926	1234	985	935	864	1034
1530000	0.51	2097	1188	1220	1262	1206	1270
1560000	0.52	2105	1185	1211	1266	1224	1247
1590000	0.53	2110	1179	1238	1284	1226	1247
1620000	0.54	2098	1201	1237	1270	1225	1248
1650000	0.55	2096	1208	1200	1300	1219	1254
1680000	0.56	2112	1189	1213	1260	1206	1266
1710000	0.57	2100	1183	1204	1244	1211	1363
1740000	0.58	2091	1226	1202	1246	1210	1438
1770000	0.59	2102	1204	1206	1288	1287	1651
1800000	0.6	2092	1202	1201	1269	1253	1748
1830000	0.61	2104	1284	1197	1256	1243	1478
1860000	0.62	2139	1249	1203	1253	1232	1524

1890000	0.63	2117	1233	1259	1391	1258	1351
1920000	0.64	2108	1277	1213	1321	1217	1353
1950000	0.65	2090	1185	1244	1286	1216	1357
1980000	0.66	2097	1176	1232	1295	1215	1371
2010000	0.67	2129	1178	1264	1360	1242	1397
2040000	0.68	2101	1175	1213	1297	1283	1315
2070000	0.69	2096	1175	1246	1298	1230	1241
2100000	0.7	2098	1175	1216	1325	1206	1254
2130000	0.71	2093	1183	1210	1342	1210	1261
2160000	0.72	2106	1249	1234	1314	1208	1286
2190000	0.73	2104	1182	1561	1243	1203	1280
2220000	0.74	2099	1192	1947	1291	1208	1269
2250000	0.75	2097	1356	1218	1244	1200	1266
2280000	0.76	2105	1373	1223	1251	1229	1367
2310000	0.77	2097	1829	1299	1268	1212	1337
2340000	0.78	2107	1473	1244	1269	1207	1328
2370000	0.79	2102	1208	1265	1256	1209	1296
2400000	0.8	2096	1230	1245	1288	1207	1291
2430000	0.81	2103	1191	1237	1376	1206	1330
2460000	0.82	2095	1183	1207	1293	1206	1305
2490000	0.83	2087	1182	1219	1309	1198	1309
2520000	0.84	2092	1184	1268	1290	1208	1327
2550000	0.85	2089	1193	1341	1334	1209	1237
2580000	0.86	2093	1191	1562	1336	1213	1239
2610000	0.87	2097	1190	1442	1366	1206	1251
2640000	0.88	2098	1191	1617	1343	1204	1248
2670000	0.89	2132	1185	1246	1248	1253	1286
2700000	0.9	2201	1180	1209	1233	1339	1290
2730000	0.91	2230	1222	1201	1240	1438	1303
2760000	0.92	2455	1212	1200	1238	1700	1607
2790000	0.93	2120	1220	1198	1241	1724	1794
2820000	0.94	2113	1181	1199	1250	1422	1509
2850000	0.95	2110	1188	1202	1274	1384	1391
2880000	0.96	2096	1193	1206	1261	1250	1377
2910000	0.97	2095	1181	1209	1270	1206	1360
2940000	0.98	2108	1191	1200	1313	1217	1341
2970000	0.99	2109	1253	1227	1344	1207	1377
3000000	1	2098	1181	1280	1306	1265	1377

Cutoff vs time



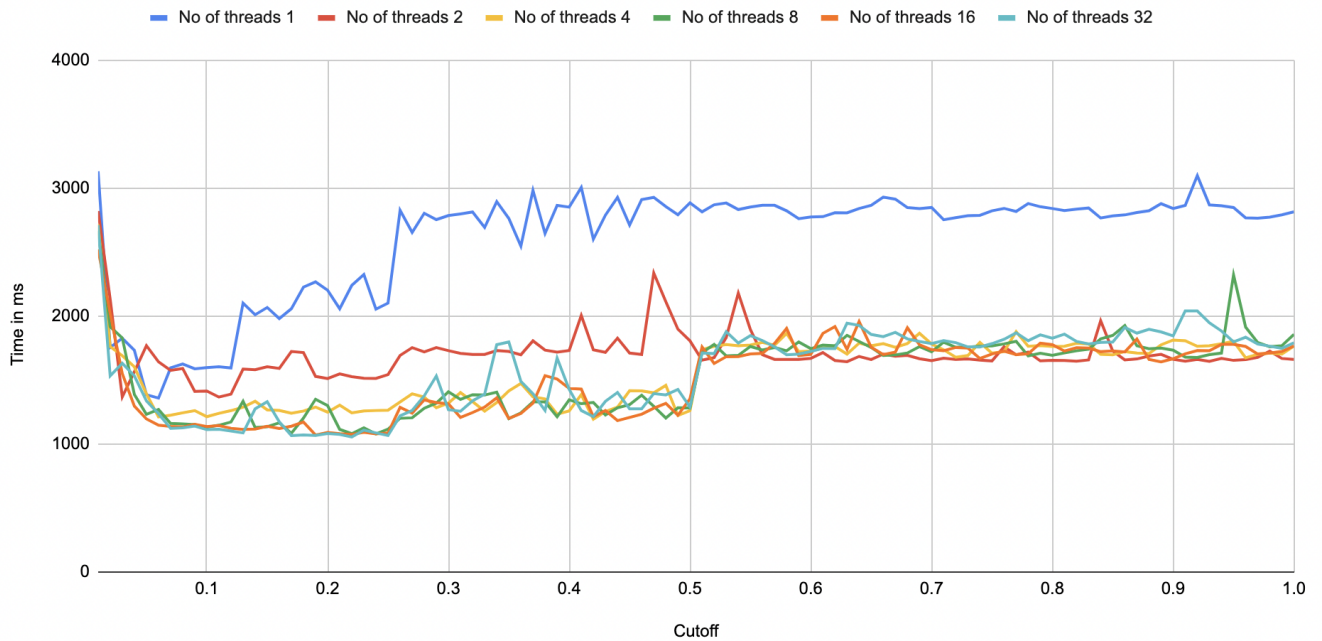
3) For Array size = 4,000,000

Cutoff	Cutoff percentage	No of threads 1	No of threads 2	No of threads 4	No of threads 8	No of threads 16	No of threads 32
40000	0.01	3132	2821	2717	2664	2521	2711
80000	0.02	1754	2132	1761	1916	2018	1532
120000	0.03	1826	1367	1690	1829	1550	1631
160000	0.04	1733	1564	1603	1387	1296	1532
200000	0.05	1385	1768	1392	1231	1195	1336
240000	0.06	1358	1642	1211	1269	1146	1236
280000	0.07	1594	1575	1224	1160	1137	1121
320000	0.08	1625	1590	1243	1156	1132	1125
360000	0.09	1587	1411	1260	1151	1153	1139
400000	0.1	1597	1413	1213	1130	1135	1111
440000	0.11	1604	1366	1239	1146	1143	1114
480000	0.12	1594	1389	1260	1171	1122	1101
520000	0.13	2101	1585	1287	1333	1113	1086
560000	0.14	2010	1580	1333	1128	1116	1274
600000	0.15	2067	1603	1266	1134	1138	1330
640000	0.16	1980	1590	1262	1165	1120	1172
680000	0.17	2057	1723	1240	1083	1138	1065
720000	0.18	2226	1714	1257	1202	1171	1070
760000	0.19	2267	1528	1288	1349	1069	1066
800000	0.2	2202	1511	1248	1299	1089	1081

840000	0.21	2057	1547	1303	1113	1080	1074
880000	0.22	2240	1526	1243	1080	1074	1054
920000	0.23	2325	1513	1257	1126	1091	1107
960000	0.24	2054	1512	1261	1078	1078	1086
1000000	0.25	2101	1542	1263	1115	1085	1066
1040000	0.26	2827	1692	1328	1200	1286	1219
1080000	0.27	2654	1753	1392	1204	1240	1261
1120000	0.28	2804	1720	1366	1279	1344	1376
1160000	0.29	2754	1753	1283	1319	1323	1531
1200000	0.3	2786	1729	1319	1407	1313	1268
1240000	0.31	2799	1708	1401	1348	1207	1255
1280000	0.32	2814	1700	1330	1384	1245	1337
1320000	0.33	2693	1700	1256	1382	1288	1388
1360000	0.34	2895	1730	1323	1405	1360	1776
1400000	0.35	2764	1723	1414	1197	1199	1797
1440000	0.36	2547	1697	1473	1242	1238	1489
1480000	0.37	2983	1806	1368	1328	1319	1392
1520000	0.38	2646	1733	1352	1329	1533	1261
1560000	0.39	2865	1717	1232	1212	1507	1671
1600000	0.4	2852	1730	1258	1345	1434	1426
1640000	0.41	3006	2005	1385	1314	1429	1261
1680000	0.42	2601	1736	1193	1324	1213	1213
1720000	0.43	2789	1716	1253	1226	1261	1333
1760000	0.44	2929	1827	1287	1282	1182	1402
1800000	0.45	2712	1710	1416	1307	1207	1274
1840000	0.46	2911	1699	1414	1381	1232	1274
1880000	0.47	2928	2337	1399	1294	1279	1393
1920000	0.48	2856	2112	1458	1202	1317	1383
1960000	0.49	2792	1897	1222	1283	1225	1426
2000000	0.5	2885	1806	1260	1281	1353	1288
2040000	0.51	2815	1655	1738	1713	1758	1711
2080000	0.52	2870	1675	1763	1778	1629	1706
2120000	0.53	2884	1832	1777	1688	1682	1877
2160000	0.54	2833	2179	1767	1692	1683	1788
2200000	0.55	2853	1894	1773	1762	1703	1847
2240000	0.56	2867	1697	1794	1735	1708	1808
2280000	0.57	2866	1661	1771	1754	1786	1759
2320000	0.58	2823	1661	1864	1728	1903	1697
2360000	0.59	2761	1660	1721	1797	1691	1702
2400000	0.6	2775	1669	1726	1745	1700	1723

2440000	0.61	2777	1714	1749	1773	1864	1747
2480000	0.62	2808	1652	1762	1767	1918	1745
2520000	0.63	2807	1643	1702	1849	1739	1944
2560000	0.64	2841	1684	1788	1801	1957	1927
2600000	0.65	2866	1660	1767	1754	1756	1856
2640000	0.66	2930	1702	1784	1691	1698	1839
2680000	0.67	2914	1685	1756	1696	1718	1872
2720000	0.68	2848	1692	1785	1711	1908	1821
2760000	0.69	2840	1666	1865	1761	1775	1801
2800000	0.7	2849	1651	1781	1721	1737	1784
2840000	0.71	2753	1670	1736	1795	1729	1808
2880000	0.72	2769	1661	1677	1756	1754	1792
2920000	0.73	2784	1664	1691	1757	1750	1759
2960000	0.74	2788	1655	1794	1765	1668	1758
3000000	0.75	2823	1649	1709	1766	1703	1784
3040000	0.76	2842	1760	1722	1782	1726	1818
3080000	0.77	2818	1697	1877	1802	1698	1868
3120000	0.78	2880	1718	1763	1688	1705	1807
3160000	0.79	2855	1649	1769	1709	1788	1853
3200000	0.8	2841	1654	1762	1692	1776	1826
3240000	0.81	2825	1652	1763	1712	1726	1858
3280000	0.82	2836	1647	1787	1728	1752	1801
3320000	0.83	2845	1657	1781	1740	1750	1781
3360000	0.84	2767	1963	1700	1821	1721	1794
3400000	0.85	2783	1726	1696	1848	1727	1796
3440000	0.86	2791	1657	1722	1926	1719	1911
3480000	0.87	2810	1664	1711	1767	1820	1866
3520000	0.88	2823	1687	1706	1744	1661	1896
3560000	0.89	2879	1700	1775	1749	1641	1876
3600000	0.9	2841	1661	1812	1733	1666	1845
3640000	0.91	2865	1647	1807	1679	1704	2040
3680000	0.92	3098	1660	1763	1676	1730	2040
3720000	0.93	2869	1645	1767	1698	1728	1947
3760000	0.94	2863	1669	1783	1710	1778	1883
3800000	0.95	2849	1653	1802	2322	1779	1798
3840000	0.96	2768	1659	1673	1913	1762	1834
3880000	0.97	2765	1677	1700	1793	1703	1781
3920000	0.98	2774	1726	1711	1760	1710	1764
3960000	0.99	2792	1668	1703	1768	1723	1747
4000000	1	2815	1661	1765	1856	1766	1791

Cutoff vs time



Conclusions:

1. The performance of parallel sort is best when the cutoff is between 20% - 50% of the array size and thread count is between 2^3 and 2^5 .
2. As the thread count increases the time taken reduces. For 1 thread the time taken is more than time taken for 2 and 4 threads.
3. For Thread count after 4, the performance remains almost the same.
4. The performance degrades and remains constant for thread counts(8-32) when the cutoff is above 50% of the array size.