Project Report: Performance Evaluation of Various Sorting Algorithms

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I. Introduction

FOR the project, we were tasked to compare the performance of the different sorting algorithms both serialized and parallel. We were tasked to compare them in terms of time complexities (both theoretical and experimental running times), speedup, and efficiency, as well as to determine on whether it is worth coding in parallel.

The data will be tabulated, graphed, and presented below. The values used are N = 1000, 2000, 3000, ..., 500000. However, special cases have been made for one of the sorting algorithms wherein once the N value reached 150000, the increments are increased to 50000. This is due to the slow nature of that specific algorithm. More will be detailed in the following section.

II. Device Specifications

THE device used for experimentation was a mid-2012 MacBook Pro that was running a virtual machine. The specifications of the hardware components in use when the virtual machine was running is listed below:

- **Processor**: Dual-Core Intel Core i5 (I5-3210M)
- **Number of Processors Used**: 1
- **Logical Processors Used**: 2
- **Memory**: 3 GB 1600 MHz DDR3
- **Clock Rate**: 2.5 GHz, with Turbo Boost of up to 3.1 GHz.
- **Operating System**: Ubuntu 20.04
- **L1 Cache**: 32k/32k x2
- **Other Applications Running During the Test**: Sublime Text and System Monitor

III. Algorithms Used

THE algorithms that will be discussed are Bubble Sort, Bucket Sort, Merge Sort, and Shell Sort. Both Serial and Parallel implementations have been tested under the conditions set :

- **Bubble Sort**: Usually the first sorting algorithm we are made familiar with. Bubble Sort works by comparing consecutive elements, swapping the pairs such that the smallest element goes first until reaching the end of the list. The process then repeats until the array is fully sorted[1].
- **Bucket Sort**: This is a comparison-sort algorithm in which the elements are grouped into 'buckets' with predetermined ranges, after which these buckets are sorted using an algorithm, and finally get merged back into one, sorted list[1].
- **Merge Sort**: Merge Sort uses a divide-and-conquer approach, in which the initial list is recursively split in half until the sublist only has one element, then resursively merged in such a way that the resultant sublists are sorted[1].
- **Shell Sort**: This is a sorting algorithm in between Bubble Sort and Insertion Sort. The general idea here is that the algorithm first sort elements that are far apart, then proceeds to progressively reduce the gap between the elements to be compared and sorted[2].

IV. Implementation

THE algorithms were implemented in two categories: Serial and Parallel.

For the Serial implementation, it is the standard algorithm implementation wherein we do not optimized it in any way we can so that it runs faster; the standard implementation so to speak.

For the Parallel implementation, we incorporated some of the concepts that were discussed in the laboratory handouts, namely threading and setting the core-affinity of a certain process.

We do this by partitioning the array to be sorted based on how many processors are made available by the user. Afterwards, we proceed to assign a thread–that is in turn, assigned to a specific core of the processor–to each partition that sort the specific partition using the specific sorting algorithm being evaluated.

Next, we then merge all of the sorted partitions into one final, sorted array. The speed of the parallel implementation of the algorithm is highly reliant on the number of cores the user's device is working on.

V. Theoretical Running Time

THE algorithms to be evaluated have their worst-case running times listed below. Take note that these are in Big-O notation.

- **Bubble Sort**: Bubble Sort's worst-case running time is $O(n^{[2]})$[3].
- **Bucket Sort**: Bucket Sort's worst-case running time is also $O(n^{[2]})$[3].
- **Merge Sort**: Merge Sort's worst-case running time is O(n log n)[3].

- **Shell Sort**: Shell Sort's worst-case running time varies from $O(n^2)$ to $O(n \log n)$[4].
  Other modifications have been made to the algorithms. These will be discussed in the discussion portion of the paper.

VI. Theoretical Running Time Graphs

THE values displayed in the graphs below show the theoretical values of the algorithms based on the input size, as well as the experimental running times conducted. Take not that these also apply for the parallel implementations as we are talking about time complexity, and not execution time.

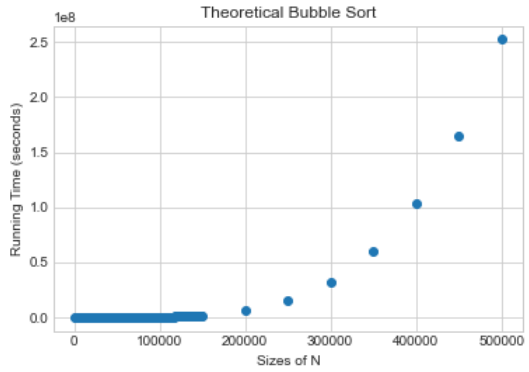

Figure 1: Theoretical Running Time Graph of Bubble Sort

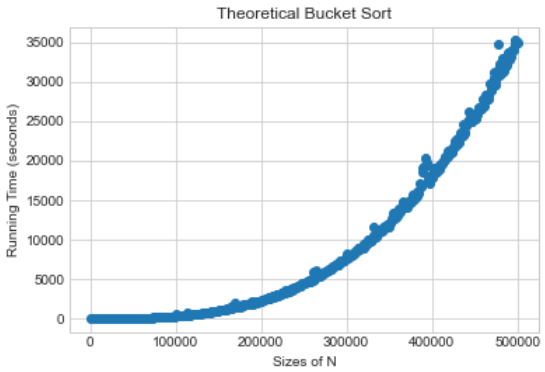

Figure 2: Theoretical Running Time Graph of Bucket Sort

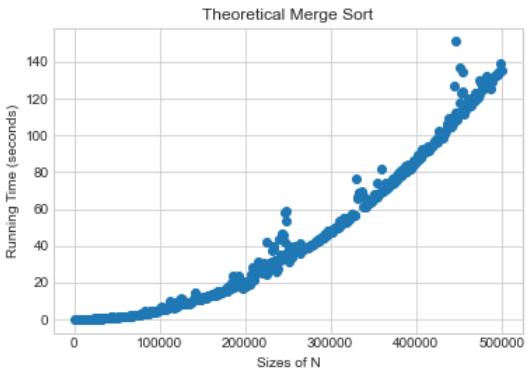

Figure 3: Theoretical Running Time Graph of Merge Sort

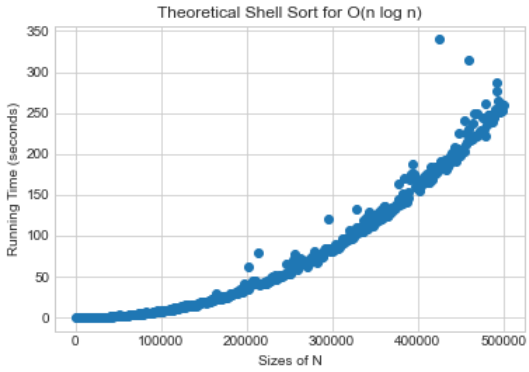

Figure 4: Theoretical Running Time Graph of Shell Sort for O(n log n)

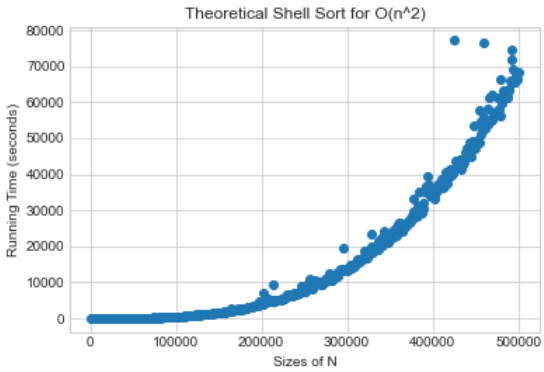

Figure 5: Theoretical Running Time Graph of Shell Sort for $O(n^{[2]})$

VII. Results

FOR uniformity, the test cases were chosen to be $N = \{1000, 2000, 3000, ..., 500000\}$. However, special cases have been made for one of the sorting algorithms wherein once the N value reached 150000, the increments are increased to 50000., as these are the test cases in which all algorithms have similarities at.

The graphs of the values of the experimental running times are shown below. All of the tabulated data will be put in the appedix of this paper.

The Python script used in processing the data is included in the code repository submitted with this paper.

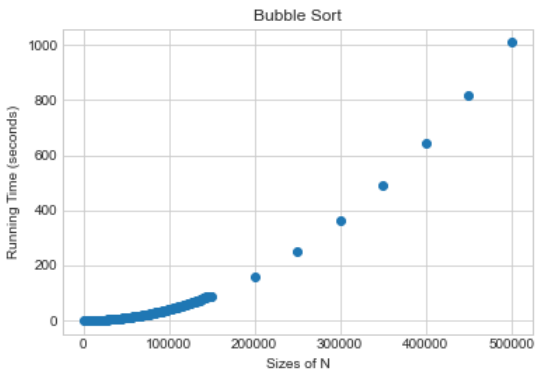

Figure 6: Experimental Running Time Graph of Bubble Sort

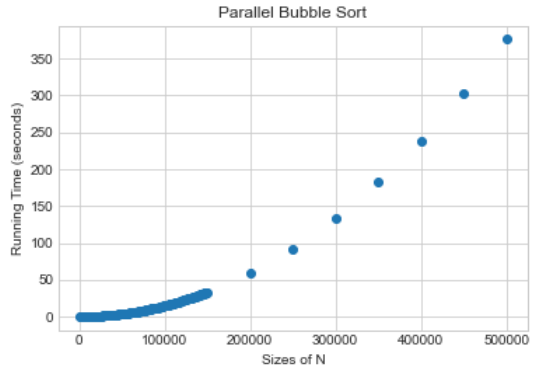

Figure 7: Experimental Running Time Graph of Parallel Bubble Sort

With Bubble Sort's Serial and Parallel implementation, comparing the algorithm's theoretical running time in Figure 1 to those of Figures 6 and 7. We can clearly see that all three graphs follow the trend of the curve, kind of like a one-sided parabola. We have difficulties seeing this in Figure 1 due to the scale of the theoretical values that were computed, due to it being quadratic in nature.

However, we can safely infer that based on the trends and the data gathered that is listed in the appendix of this paper, the theoretical and experimental values of the results gathered from Bubble Sort match and are accurate.

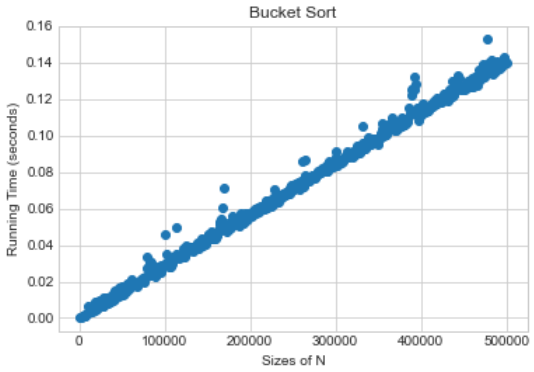

Figure 8: Experimental Running Time Graph of Bucket Sort

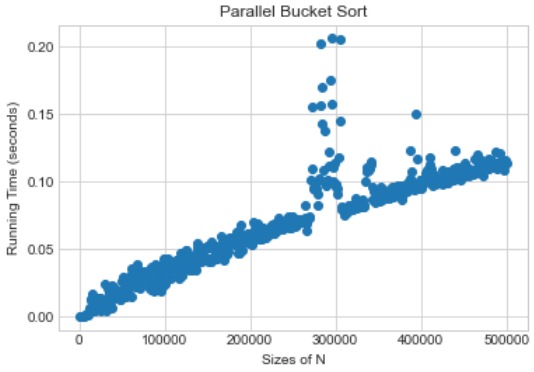

Figure 9: Experimental Running Time Graph of Parallel Bucket Sort

Proceeding to Bucket Sort, we get to see a difference in the Serial and Parallel Implementations of the algorithm, specifically in Figure 9, because at around N = 300000, we get to see a weird deviation in the running times of the parallel algorithm, with the point values going as far as reaching running times greater than that of the running time of the largest N value of its serial counterpart.

Due to the nature of the deviation, it can likely be attributed to the CPU adjusting the power it is alloting to the program. From my observation of the System Monitor during runtime. I always noticed that for the relatively smaller sizes of N, the CPU tends to not utilize all of the power it has alloted–usually it only utilizes around 50%–to the processes.

Moreover, if we compare Figures 8 and 9 with their theoretical running time displayed in Figure 2. We get to see a stark difference in the trends of the graphs, with the theoretical graph following a quadratic trend. This is mainly due to the modifications made for Bucket Sort.

In most cases, Bucket Sort's sorting mechanism is either done through recursively doing Bucket Sort on to the buckets, or through Insertion Sort. The student thought it would prove to be faster had they implement a subjectively faster algorithm in mind. With that being said, the student had decided to use Merge Sort as the sorting algorithm of choice in sorting through the buckets that Bucket Sort implements. This explains why Bucket Sort's running times–both experimental and theoretical– resemble that of Merge Sort's, with the difference mainly being in execution time, based on the figures shown..

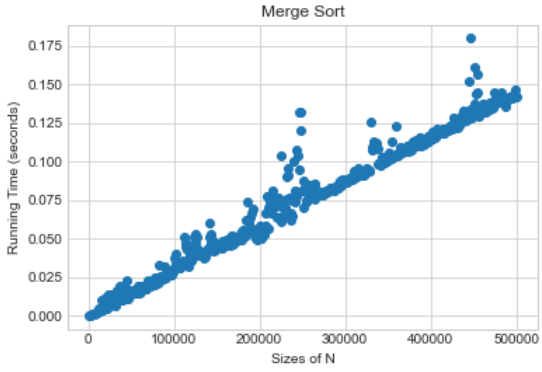

Figure 10: Experimental Running Time Graph of Merge Sort

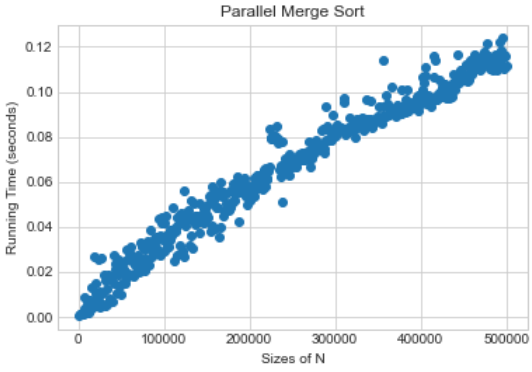

Figure 11: Experimental Running Time Graph of Parallel Merge Sort

As for Merge Sort, we can see from Figures 10 and 11 that the main changes from the serial and parallel implementation of this algorithm is the execution time. Both implementation closely resemble the graph of their theoretical counterpart in Figure 3.

In addition, we can see that deviations became more common in the parallel implementation than that in the serial implementation as the scatter plot became more dense. Nonetheless, the graph still follows the general trend of the function running time.

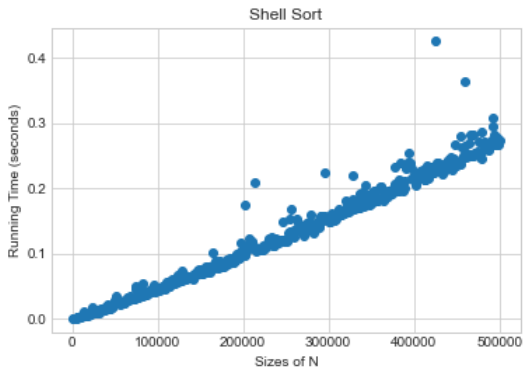

Figure 12: Experimental Running Time Graph of Shell Sort

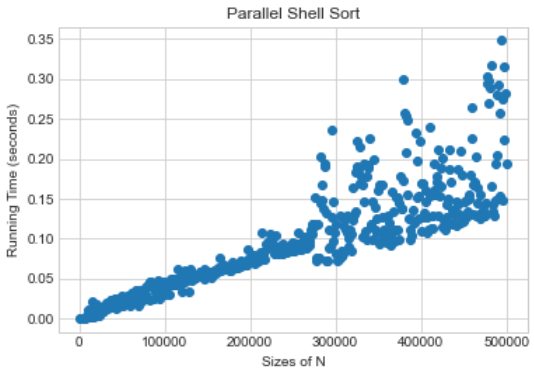

Figure 13: Experimental Running Time Graph of Parallel Shell Sort

For Shell Sort, things become rather interesting. We can see from Figures 12 and 13 that Figure 13 has a lot more deviation than that of Figure 12, yet we can infer from the scatter plot that the execution time of the parallel implementation is still mostly faster than that of the serial implementation.

This deviation in plot points not only stems from the memory and CPU usage of the algorithm, but also from the device limitations. When the experiment for the parallel implementation of shell sort was ongoing, I noticed that there were times when the virtual machine was lagging, even going as far as hanging for a second or two, signifying that the algorithm, while it was working, was using too much memory.

VIII. Discussion

Based purely on the data above, we can already see that the execution time of the theoretical running times are significantly larger than that of the experimental running time. This is primarily due to the fact that the computation on the theoretical data doesn't account for other factors such as speed of device, memory available, et cetera.

Furthermore, since most of the algorithms being tested save for Bubble Sort had an average case complexity of O(n log n). We focus on the average case because due to the randomization function implemented, we are, at most times, guaranteed a random function based on the device of the user.

Testing them under the conditions set by the specifications would prove impossible on our devices as we'd encounter memory allocation problems first because of the limitations of the maximum allotment of memory space by the programming language used, as well as the hardware limitations.

In addition, the growth rate of Bubble Sort compared to other algorithms is exponential, while the others are log-linear. While both do go on and extend up until infinity, log-linear algorithms will extend up to infinity far slower than exponential algorithms will[5].

Due to this, the analysis of the other algorithms were stopped at the same size of N as with Bubble Sort. This allows us for easier comparison time as all of the graphs have the same start and end points, albeit with a few considerations made for Bubble Sort.

Now, focusing on the algorithms at hand, we can clearly see that for both parallel and serial, they've retained their running times based on our analyses. The main difference that they offer is that the parallel implementation's execution time is faster in varying degrees compared to that of the serial implementation.

We notice this most for Bubble Sort's Parallel Implementation. Upon referring to the appendix made available at the end of this file, we can compute for a 1.3x speedup for N = 1000 and a 2.68x speedup for N = 500000. This gives us the idea that parallelizing Bubble Sort does give benefits for its execution time, even though it does nothing for its time complexity, which is useful in practical applications.

But this is not the case for all algorithms, when we take a look at the data available for Merge Sort, we can compute for a 0.33x speedup for N = 1000 and a 1.28x speedup for N = 500000. This now provides us with the idea that not all algorithms are suitable for parallelization if their input cases are only small numbers. However, this should not be taken as discouragement from implementing parallelization on this specific algorithm since most practical applications of these algorithms deal with multiple amounts of data, hence the importance of the concept.

IX. Conclusion and Recommendation

Overall, we get the general idea that while parallelization is a beneficial way of improving execution time. There can be a lot of factors that affect the efficiency and effectiveness of parallelization in theoretical and practical applications of the sorting algorithms. Nonetheless, these still prove that parallelization is worth it, if applied under the right circumstances for the right problems to be addressed.

In addition, we can see that the best implementation in terms of execution time remains to be the parallel algorithm for

Merge sort. However, it is important to note that the parallel implementation of Merge sort only remains to be the best algorithm to be used due to the nature of the input sizes the algorithm was tested on, since Merge sort performs best under large input sizes because of its constant running time at the best, average, and worst case scenarios. As mentioned in the previous section, Parallelized Merge Sort still works horrendously under small input cases.

Other factors that can further this research include the improvement of the memory usage and allocation of each one of the algorithms since the current implementation wastes a lot of allocated memory space, implementation on a much faster device to see if the outlier data in the graphs and tables are hardware caused or algorithm caused, and the addition of other metrics of measuring performance.

X. References

[1]. Bell, A., Grimson, E., Guttag, J. (2016). Lecture 12: Searching and Sorting [PowerPoint slides]. MIT Open Courseware: https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-0001-introduction-to-computer-science-and-programming-in-python-fall-2016/lecture-slides-code/MIT$6_0001F16_Lec12.pdf$

[2]. Knuth, Donald E. (1997). "Shell's method". The Art of Computer Programming. Volume 3: Sorting and Searching (2nd ed.). Reading, Massachusetts: Addison-Wesley. pp. 83–95. ISBN 978-0-201-89685-5.

[3]. Time Complexities of all Sorting Algorithms. GeeksforGeeks. (2020, September 29). https://www.geeksforgeeks.org/time-complexities-of-all-sorting-algorithms/.

[4]. Pratt, Vaughan Ronald (1979). Shellsort and Sorting Networks (Outstanding Dissertations in the Computer Sciences). Garland. ISBN 978-0-8240-4406-0.

[5]. https://www.quora.com/Is-there-a-difference-between-logarithmic-and-exponential-growth

APPENDIX A: Tables

Bubble Sort

N	seconds	theo_seconds
1000	0.003565	0.003565
2000	0.015141	0.060564
3000	0.046855	0.421695
4000	0.070342	1.125472
5000	0.091506	2.28765
6000	0.132276	4.761936
7000	0.184651	9.047899
8000	0.236393	15.129152
9000	0.29753	24.09993
10000	0.378162	37.8162
11000	0.453515	54.875315
12000	0.537435	77.39064
13000	0.658809	111.338721
14000	0.763725	149.6901
15000	0.861112	193.7502
16000	0.966433	247.406848
17000	1.105898	319.604522
18000	1.251759	405.569916
19000	1.397301	504.425661
20000	1.540992	616.3968
21000	1.703815	751.382415
22000	1.88946	914.49864
23000	2.037102	1077.626958
24000	2.22679	1282.63104
25000	2.447129	1529.455625
26000	2.663776	1800.712576
27000	2.875339	2096.122131
28000	3.053426	2393.885984
29000	3.339572	2808.580052
30000	3.483362	3135.0258
31000	3.797562	3649.457082
32000	3.994837	4090.713088
33000	4.265095	4644.688455
34000	4.572658	5285.992648
35000	4.787022	5864.10195
36000	5.32734	6904.23264
37000	5.433525	7438.495725
38000	5.662947	8177.295468
39000	6.016175	9150.602175
40000	6.291722	10066.7552
41000	6.604895	11102.828495
42000	6.924546	12214.899144
43000	7.328777	13550.908673
44000	7.846922	15191.640992
45000	7.964446	16128.00315
46000	8.335938	17638.844808
47000	8.703881	19226.873129
48000	9.17688	21143.53152
49000	9.497867	22804.378667
50000	9.908076	24770.19
51000	10.37561	26986.96161
52000	10.673642	28861.527968
53000	11.195491	31448.134219
54000	11.654185	33983.60346
55000	11.996633	36289.814825
56000	12.513601	39242.652736
57000	12.955997	42094.034253
58000	13.48327	45357.72028
59000	13.78867	47998.36027
60000	14.338119	51617.2284
61000	14.835322	55202.233162
62000	15.282794	58747.060136
63000	15.732163	62440.954947
64000	16.280592	66685.304832
65000	17.057003	72065.837675
66000	17.437117	75956.081652
67000	17.805006	79926.671934
68000	18.245483	84367.113392
69000	18.913847	90048.825567
70000	19.408227	95100.3123
71000	19.99877	100813.79957
72000	20.673249	107170.122816
73000	21.156488	112742.924552
74000	21.686332	118754.354032
75000	22.342779	125678.131875
76000	22.921278	132393.301728
77000	23.488999	139266.275071
78000	24.071908	146453.488272
79000	24.782612	154668.281492
80000	25.332532	162128.2048
81000	26.164883	171667.797363
82000	26.625065	179026.93706
83000	27.239462	187652.653718
84000	28.166345	198741.73032
85000	29.447359	212757.168775
86000	29.474581	217994.001076
87000	30.089739	227749.234491
88000	30.742198	238067.581312
89000	31.603591	250332.044311
90000	32.210422	260904.4182
91000	32.958064	272925.727984
92000	33.681113	285076.940432
93000	34.391102	297448.641198
94000	35.391272	312717.279392
95000	35.871103	323736.704575
96000	36.796647	339117.898752
97000	37.419951	352084.318959
98000	38.195621	366830.744084
99000	39.039118	382622.395518
100000	39.840661	398406.61
101000	40.567512	413829.189912
102000	41.463619	431387.492076
103000	42.590537	451843.007033
104000	43.218745	467453.94592
105000	44.020386	485324.75565
106000	45.043067	506103.900812
107000	45.701581	523237.400869
108000	46.557374	543045.210336
109000	47.437102	563600.208862
110000	48.405506	585706.6226
111000	49.277855	607152.451455
112000	50.004553	627257.112832
113000	50.936302	650405.640238
114000	52.577832	683301.504672
115000	52.869062	699193.34495
116000	53.837875	724442.446
117000	54.858128	750952.914192
118000	56.548097	787375.702628
119000	56.565147	801019.046667
120000	57.547026	828677.1744
121000	58.495419	856431.429579
122000	60.086978	894334.580552
123000	60.494984	915228.612936
124000	61.319017	942841.205392

125000	62.230202	972346.90625
126000	63.444606	1007246.564856
127000	64.556324	1041228.949796
128000	65.416547	1071784.706048
129000	66.499306	1106614.951146
130000	67.566715	1141877.4835
131000	69.386711	1190745.347471
132000	69.708117	1214594.230608
133000	70.619211	1249183.223379
134000	71.739774	1288159.381944
135000	72.924121	1329042.105225
136000	74.071497	1370026.408512
137000	75.200759	1411443.045671
138000	76.037405	1448056.34082
139000	79.083111	1527964.787631
140000	80.420725	1576246.21
141000	81.181464	1613968.685784
142000	82.849827	1670583.911628
143000	83.658081	1710724.098369
144000	85.708027	1777241.647872
145000	85.159076	1790469.5729
146000	85.269571	1817606.175436
147000	86.2985	1864824.2865
148000	87.705493	1921101.118672
149000	89.087624	1977834.340424
150000	89.922118	2023247.655
200000	159.974741	6398989.64
250000	250.964909	15685306.8125
300000	361.664997	32549849.73
350000	493.202313	60417283.3425
400000	646.312885	103410061.6
450000	816.13562	165267463.05
500000	1009.396752	252349188

Parallel Bubble Sort

N	seconds
1000	0.002737
2000	0.014749
3000	0.026869
4000	0.04171
5000	0.074271
6000	0.072936
7000	0.096185
8000	0.127709
9000	0.135627
10000	0.160159
11000	0.200133
12000	0.225538
13000	0.261935
14000	0.29348
15000	0.339454
16000	0.393086
17000	0.424433
18000	0.48704
19000	0.553845
20000	0.596149
21000	0.655279
22000	0.709067
23000	0.7761
24000	0.832287
25000	0.915659
26000	0.977762
27000	1.097751
28000	1.227187
29000	1.263477
30000	1.314715
31000	1.404513
32000	1.512706
33000	1.627202
34000	1.756194
35000	1.811277
36000	2.123256
37000	2.013538
38000	2.140367
39000	2.236755
40000	2.381901
41000	2.509258
42000	2.61555
43000	2.779266
44000	2.88571
45000	2.952828
46000	3.286153
47000	3.676228
48000	3.485333
49000	3.499491
50000	3.923414
51000	3.81351
52000	3.943917
53000	4.059169
54000	4.200808
55000	4.792776
56000	4.572127
57000	4.93433
58000	4.895799
59000	5.026253
60000	5.207012
61000	5.595957
62000	6.021564
63000	5.849376
64000	6.014344
65000	6.363247
66000	6.508934
67000	6.452807
68000	6.739367
69000	6.8487
70000	7.312961
71000	7.428921
72000	7.618395
73000	7.751734
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75000	8.084726
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78000	8.975383
79000	8.984864
80000	9.802345
81000	9.705249
82000	9.728897
83000	9.990794
84000	10.47192
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86000	12.342026
87000	11.601382
88000	11.411829
89000	11.726601
90000	11.776619

91000	12.024895
92000	12.549485
93000	12.556506
94000	13.339462
95000	13.299692
96000	13.607796
97000	13.650214
98000	13.92254
99000	14.835121
100000	14.689508
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108000	17.050097
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110000	17.88161
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112000	18.45995
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115000	19.738605
116000	19.933971
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118000	20.407204
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124000	22.414324
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126000	23.327757
127000	24.252829
128000	24.31225
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139000	28.726805
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143000	30.016237
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145000	30.730725
146000	31.265443
147000	31.644379
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149000	32.86671
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Bucket Sort

N	seconds	theo_seconds
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3000	**0.000658**	**0.005922**
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5000	**0.001252**	**0.0313**
6000	**0.001418**	**0.051048**
7000	**0.001522**	**0.074578**
8000	**0.001704**	**0.109056**
9000	**0.002968**	**0.240408**
10000	**0.002383**	**0.2383**
11000	**0.006291**	**0.761211**
12000	**0.003192**	**0.459648**
13000	**0.005416**	**0.915304**
14000	**0.004672**	**0.915712**
15000	**0.003655**	**0.822375**
16000	**0.004534**	**1.160704**
17000	**0.003879**	**1.121031**
18000	**0.004152**	**1.345248**
19000	**0.008804**	**3.178244**
20000	**0.00527**	**2.108**
21000	**0.005322**	**2.347002**
22000	**0.005398**	**2.612632**
23000	**0.006889**	**3.644281**
24000	**0.009591**	**5.524416**
25000	**0.007901**	**4.938125**
26000	**0.006182**	**4.179032**
27000	**0.006806**	**4.961574**
28000	**0.006804**	**5.334336**
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30000	**0.007715**	**6.9435**
31000	**0.008829**	**8.484669**
32000	**0.011417**	**11.691008**
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34000	**0.008138**	**9.407528**
35000	**0.010435**	**12.782875**
36000	**0.011437**	**14.822352**
37000	**0.008977**	**12.289513**
38000	**0.012442**	**17.966248**
39000	**0.010425**	**15.856425**
40000	**0.009962**	**15.9392**
41000	**0.015243**	**25.623483**
42000	**0.010146**	**17.897544**
43000	**0.013752**	**25.427448**
44000	**0.01207**	**23.36752**
45000	**0.011708**	**23.7087**
46000	**0.016595**	**35.11502**
47000	**0.01204**	**26.59636**
48000	**0.015522**	**35.762688**
49000	**0.016481**	**39.570881**
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52000	**0.016436**	**44.442944**
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63000	0.018561	73.668609
64000	0.018521	75.862016
65000	0.018263	77.161175
66000	0.018092	78.808752
67000	0.019805	88.904645
68000	0.017163	79.361712
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74000	0.020314	111.239464
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76000	0.019747	114.058672
77000	0.021616	128.161264
78000	0.022429	136.458036
79000	0.033709	210.377869
80000	0.027736	177.5104
81000	0.028298	185.663178
82000	0.029403	197.705772
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85000	0.023407	169.115575
86000	0.023428	173.273488
87000	0.024302	183.941838
88000	0.026393	204.387392
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90000	0.024467	198.1827
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95000	0.024675	222.691875
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457000	0.126969	26517.348681
458000	0.126889	26616.744196
459000	0.128601	27093.787281
460000	0.131768	27882.1088
461000	0.126728	26932.361288
462000	0.129494	27639.717336
463000	0.132565	28417.826485
464000	0.13145	28300.6592
465000	0.129067	27907.512075
466000	0.127835	27760.13726
467000	0.129338	28207.195082
468000	0.136333	29860.198992
469000	0.132475	29139.333475
470000	0.130987	28935.0283
471000	0.13448	29833.17768
472000	0.136925	30504.6992
473000	0.139297	31164.778513
474000	0.13198	29652.73848
475000	0.133475	30115.296875
476000	0.136667	30965.462192
477000	0.152689	34741.175481
478000	0.138624	31673.366016
479000	0.134279	30809.108039
480000	0.139903	32233.6512
481000	0.138084	31947.252324
482000	0.134269	31193.911156
483000	0.141426	32993.130114
484000	0.133742	31329.865952
485000	0.136284	32057.4039
486000	0.134941	31872.524436
487000	0.136086	32275.380534
488000	0.135058	32163.252352
489000	0.140735	33652.693935
490000	0.136772	32838.9572
491000	0.136551	32919.851631
492000	0.137027	33169.303728
493000	0.139588	33926.723812
494000	0.139683	34087.680588
495000	0.139179	34102.334475
496000	0.138325	34030.1632
497000	0.142718	35252.630462
498000	0.140376	34813.809504
499000	0.140826	35065.814826
500000	0.139942	34985.5

Parallel Bucket Sort

N	seconds
1000	0.000394
2000	0.000429
3000	0.000565
4000	0.000741
5000	0.000801
6000	0.000921
7000	0.001094
8000	0.001196
9000	0.001403
10000	0.003612
11000	0.001831
12000	0.007108
13000	0.012563
14000	0.012779
15000	0.004243
16000	0.01726
17000	0.006359
18000	0.004734
19000	0.012195
20000	0.006803
21000	0.006447
22000	0.013988
23000	0.007294
24000	0.009867
25000	0.014017
26000	0.005145
27000	0.011062
28000	0.013426
29000	0.008363
30000	0.024427
31000	0.004877
32000	0.012828
33000	0.0213
34000	0.013998
35000	0.018333
36000	0.014144
37000	0.008436
38000	0.006895
39000	0.02341
40000	0.022059
41000	0.015738
42000	0.019374
43000	0.020156
44000	0.014372
45000	0.014574
46000	0.019123
47000	0.019369
48000	0.012578
49000	0.01256
50000	0.026426
51000	0.029539
52000	0.018785
53000	0.024222
54000	0.026567
55000	0.014791
56000	0.024098
57000	0.024381
58000	0.016876
59000	0.022081
60000	0.030963
61000	0.015419
62000	0.036008
63000	0.028426
64000	0.024308
65000	0.028177
66000	0.032167
67000	0.022851
68000	0.039081

69000	0.034674
70000	0.029723
71000	0.021813
72000	0.025748
73000	0.027715
74000	0.025765
75000	0.031302
76000	0.034005
77000	0.028045
78000	0.027919
79000	0.027907
80000	0.033555
81000	0.030422
82000	0.034185
83000	0.02181
84000	0.036604
85000	0.019899
86000	0.024875
87000	0.036621
88000	0.018867
89000	0.038593
90000	0.021926
91000	0.029767
92000	0.034975
93000	0.022013
94000	0.029176
95000	0.019438
96000	0.037576
97000	0.022408
98000	0.026431
99000	0.043464
100000	0.024468
101000	0.034566
102000	0.032248
103000	0.04067
104000	0.043429
105000	0.039009
106000	0.035161
107000	0.040524
108000	0.028937
109000	0.036302
110000	0.041045
111000	0.038303
112000	0.036543
113000	0.035064
114000	0.042589
115000	0.033264
116000	0.041795
117000	0.02858
118000	0.047071
119000	0.043267
120000	0.030461
121000	0.040645
122000	0.039531
123000	0.037306
124000	0.037822
125000	0.049134
126000	0.049164
127000	0.041437
128000	0.034885
129000	0.045951
130000	0.038466
131000	0.034916
132000	0.044118
133000	0.044923
134000	0.03887
135000	0.046277
136000	0.034988
137000	0.0391
138000	0.051271
139000	0.054805
140000	0.049221
141000	0.049984
142000	0.045643
143000	0.04859
144000	0.040598
145000	0.044766
146000	0.051277
147000	0.04353
148000	0.050181
149000	0.0427
150000	0.05214
151000	0.042837
152000	0.041485
153000	0.051953
154000	0.040719
155000	0.055397
156000	0.043646
157000	0.044076
158000	0.05137
159000	0.052346
160000	0.0474
161000	0.051767
162000	0.043449
163000	0.044321
164000	0.051764
165000	0.049291
166000	0.047415
167000	0.060017
168000	0.056392
169000	0.042623
170000	0.053205
171000	0.050554
172000	0.045839
173000	0.051491
174000	0.048227
175000	0.052305
176000	0.058255
177000	0.058618
178000	0.054941
179000	0.058224
180000	0.055672
181000	0.057355
182000	0.0532
183000	0.057219
184000	0.053206
185000	0.06329
186000	0.04697
187000	0.063182
188000	0.047669
189000	0.067593
190000	0.051625
191000	0.048872
192000	0.056077
193000	0.056801
194000	0.058247
195000	0.057488
196000	0.055648
197000	0.062144

198000	0.059293
199000	0.054591
200000	0.060861
201000	0.05931
202000	0.056664
203000	0.053822
204000	0.070415
205000	0.058199
206000	0.064497
207000	0.065567
208000	0.059286
209000	0.068823
210000	0.058119
211000	0.062352
212000	0.058711
213000	0.060262
214000	0.057759
215000	0.060675
216000	0.066347
217000	0.059518
218000	0.058757
219000	0.063932
220000	0.062285
221000	0.063054
222000	0.060841
223000	0.066316
224000	0.06242
225000	0.067726
226000	0.063382
227000	0.063143
228000	0.062245
229000	0.068767
230000	0.06435
231000	0.06435
232000	0.066362
233000	0.0671
234000	0.073658
235000	0.069229
236000	0.071587
237000	0.067687
238000	0.066539
239000	0.065189
240000	0.066326

241000	0.071525
242000	0.069536
243000	0.068339
244000	0.067657
245000	0.074573
246000	0.067895
247000	0.06553
248000	0.065519
249000	0.074055
250000	0.074221
251000	0.071389
252000	0.071952
253000	0.067517
254000	0.068364
255000	0.071135
256000	0.07067
257000	0.072022
258000	0.07158
259000	0.070263
260000	0.070187
261000	0.07236
262000	0.07103
263000	0.072569
264000	0.073686
265000	0.082995
266000	0.063588
267000	0.069474
268000	0.07281
269000	0.074646
270000	0.072945
271000	0.101565
272000	0.155721
273000	0.109294
274000	0.094702
275000	0.094937
276000	0.093916
277000	0.09892
278000	0.094696
279000	0.090864
280000	0.082137
281000	0.102612
282000	0.202198
283000	0.156628

284000	0.169662
285000	0.143048
286000	0.108244
287000	0.137673
288000	0.099816
289000	0.097917
290000	0.097028
291000	0.100961
292000	0.111869
293000	0.122137
294000	0.174756
295000	0.205922
296000	0.157799
297000	0.110487
298000	0.100295
299000	0.113536
300000	0.098518
301000	0.096458
302000	0.095479
303000	0.090547
304000	0.118346
305000	0.205611
306000	0.144622
307000	0.081317
308000	0.079525
309000	0.080629
310000	0.075559
311000	0.07934
312000	0.078663
313000	0.077895
314000	0.0808
315000	0.082897
316000	0.080713
317000	0.082787
318000	0.079526
319000	0.080855
320000	0.08139
321000	0.079413
322000	0.083502
323000	0.087478
324000	0.082588
325000	0.082803
326000	0.081084

327000	0.08269
328000	0.082444
329000	0.081224
330000	0.081636
331000	0.08642
332000	0.081278
333000	0.082799
334000	0.082006
335000	0.100525
336000	0.110851
337000	0.107973
338000	0.108562
339000	0.108233
340000	0.109507
341000	0.114956
342000	0.113027
343000	0.095874
344000	0.086295
345000	0.093324
346000	0.084228
347000	0.086747
348000	0.085515
349000	0.087373
350000	0.087396
351000	0.085667
352000	0.085993
353000	0.096257
354000	0.08687
355000	0.089593
356000	0.092743
357000	0.093745
358000	0.088007
359000	0.090838
360000	0.087421
361000	0.088279
362000	0.088542
363000	0.087976
364000	0.091459
365000	0.093042
366000	0.095833
367000	0.089623
368000	0.088992
369000	0.09169

370000	0.089423
371000	0.091325
372000	0.097178
373000	0.090128
374000	0.091751
375000	0.093045
376000	0.094687
377000	0.096854
378000	0.086873
379000	0.093306
380000	0.091467
381000	0.096097
382000	0.094358
383000	0.094271
384000	0.09343
385000	0.099119
386000	0.096954
387000	0.101992
388000	0.122718
389000	0.107867
390000	0.100766
391000	0.096715
392000	0.094697
393000	0.094381
394000	0.150485
395000	0.117475
396000	0.096073
397000	0.095169
398000	0.095633
399000	0.101882
400000	0.095429
401000	0.096786
402000	0.098102
403000	0.099801
404000	0.099206
405000	0.104842
406000	0.106737
407000	0.106529
408000	0.108795
409000	0.10983
410000	0.117793
411000	0.112452
412000	0.109758

413000	0.10112
414000	0.097605
415000	0.105172
416000	0.098548
417000	0.098536
418000	0.100184
419000	0.101345
420000	0.100691
421000	0.099055
422000	0.099916
423000	0.101009
424000	0.102112
425000	0.098495
426000	0.108139
427000	0.099585
428000	0.100583
429000	0.101875
430000	0.101572
431000	0.107932
432000	0.09961
433000	0.101835
434000	0.107422
435000	0.105541
436000	0.104978
437000	0.102219
438000	0.10919
439000	0.101234
440000	0.123303
441000	0.11022
442000	0.103768
443000	0.102592
444000	0.103674
445000	0.105066
446000	0.110621
447000	0.101801
448000	0.106389
449000	0.10646
450000	0.104184
451000	0.104887
452000	0.113944
453000	0.10628
454000	0.10588
455000	0.106891

456000	0.109756
457000	0.10402
458000	0.107977
459000	0.106215
460000	0.105623
461000	0.105662
462000	0.108665
463000	0.117025
464000	0.106485
465000	0.107482
466000	0.120486
467000	0.115055
468000	0.110538
469000	0.107548
470000	0.110304
471000	0.115622
472000	0.110562
473000	0.104942
474000	0.110173
475000	0.11153
476000	0.111787
477000	0.109959
478000	0.113403
479000	0.116863
480000	0.109645
481000	0.115428
482000	0.115426
483000	0.113489
484000	0.112101
485000	0.112132
486000	0.110921
487000	0.122121
488000	0.111346
489000	0.109863
490000	0.113164
491000	0.114
492000	0.120962
493000	0.115063
494000	0.112971
495000	0.115906
496000	0.11261
497000	0.108716
498000	0.114992
499000	0.115469
500000	0.113533

Shell Sort

N	seconds	theo_sec_quad	theo_sec_log
1000	0.000222	0.000222	0.000222
2000	0.000794	0.003176	0.00174734521103813
3000	0.000728	0.006552	0.00253134427343591
4000	0.001036	0.016576	0.00497564553468769
5000	0.001377	0.034425	0.00848913615995116
6000	0.001615	0.05814	0.0122034285387392
7000	0.001747	0.085603	0.0156739013104448
8000	0.002307	0.147648	0.0240118095999744
9000	0.003266	0.264546	0.0387436681074865
10000	0.003587	0.3587	0.047826666666667
11000	0.004197	0.507837	0.0621929920318999
12000	0.004964	0.714816	0.0809962228215216
13000	0.004813	0.813397	0.0858017738701621
14000	0.011305	2.21578	0.21873589473559 8
15000	0.004941	1.111725	0.10317033455497 1
16000	0.005763	1.475328	0.12921783178691 2
17000	0.006033	1.743537	0.14462635727515 9
18000	0.00581	1.88244	0.14833879952790 1
19000	0.005932	2.141452	0.16074992028539 7
20000	0.006499	2.5996	0.18634929294546 8
21000	0.006959	3.068919	0.21054826850437 3
22000	0.006968	3.372512	0.22189200909310 7
23000	0.018441	9.755289	0.6166654431840 03
24000	0.013161	7.580736	0.46118368121732
25000	0.010225	6.390625	0.37474113823893
26000	0.013985	9.45386	0.53510948635189
27000	0.00884	6.44436	0.35255930107648 9
28000	0.009023	7.074032	0.37451593122347 5
29000	0.013916	11.703356	0.60028772854136 5
30000	0.012197	10.9773	0.54607447943815 7
31000	0.009957	9.568677	0.46211171331691 4
32000	0.013967	14.302208	0.67118325063673 7
33000	0.014385	15.665265	0.71498705327657 7
34000	0.016382	18.937592	0.84132645968184 4
35000	0.013375	16.384375	0.70906395108715 8
36000	0.014378	18.633888	0.78612620827238 5
37000	0.015603	21.360507	0.87909103517428
38000	0.013352	19.280288	0.77455742737235
39000	0.017748	26.994708	1.05926879039158
40000	0.017034	27.2544	1.04521986523041
41000	0.02271	38.17551	1.4316697256101
42000	0.019552	34.489728	1.26551278176204
43000	0.015272	28.237928	1.0142600669684 3
44000	0.019321	37.405456	1.31583685438171
45000	0.016225	32.855625	1.13247559554007
46000	0.01857	39.29412	1.32767366499301
47000	0.016654	36.788686	1.21900951104163
48000	0.02128	49.02912	1.59386901650164
49000	0.020157	48.396957	1.54415794562387

50000	0.02855	71.25	2.232010752059661
51000	0.035044	91.149444	2.804525517269999
52000	0.026982	72.959328	2.205618171777787
53000	0.025019	70.278371	2.088140957673991
54000	0.028127	82.018332	2.395944707085773
55000	0.027369	82.791225	2.378548084894008
56000	0.023694	74.304384	2.100066586088852
57000	0.02193	71.25057	1.981630376113006
58000	0.026202	88.143528	2.413019245555516
59000	0.023693	82.475333	2.2230373353328
60000	0.02623	94.428	2.506618145951256
61000	0.024741	92.061261	2.407341524109336
62000	0.025848	99.359712	2.560057301396445
63000	0.028564	113.370516	2.878855632546443
64000	0.031976	130.973696	3.278558098092999
65000	0.027596	116.5931	2.877705068114855
66000	0.030412	132.474672	3.224583343689338
67000	0.028405	127.510045	3.061557289879335
68000	0.034022	157.317728	3.726663346503401
69000	0.030455	144.996255	3.389444428343237
70000	0.030039	147.1911	3.395977667226339
71000	0.030258	152.530578	3.474015211067822
72000	0.031075	161.0928	3.622598575838444
73000	0.031262	166.595198	3.699571848491775
74000	0.04509	246.91284	5.415656903319199
75000	0.04987	280.51875	6.0779826301336
76000	0.032251	186.281776	3.987748352171088
77000	0.032778	194.35262	4.111265259926288
78000	0.037534	228.356856	4.774116849252
79000	0.034603	215.957323	4.462778209651311
80000	0.036349	232.6336	4.752597811657877
81000	0.042593	279.452673	5.644811765045655
82000	0.054241	364.716484	7.285158175901977
83000	0.03462	238.49718	4.711591378439655
84000	0.040146	283.270176	5.535323254110733
85000	0.040382	291.75995	5.640027526648844
86000	0.039203	289.945388	5.545484759810911
87000	0.036923	279.470187	5.289074211568688
88000	0.040024	309.945856	5.805007251124066
89000	0.039677	314.281517	5.825849436378229
90000	0.040283	326.2923	5.987152530232333
91000	0.043414	359.511334	6.530518631188911
92000	0.041415	350.53656	6.3043083679985
93000	0.04647	401.91903	7.157447481198344
94000	0.04518	399.21048	7.040158714669888
95000	0.052137	470.536425	8.218246560949992
96000	0.047834	440.838144	7.626302789158887
97000	0.041819	393.474971	6.742851764687339
98000	0.045106	433.198024	7.354385283426006
99000	0.047807	468.556407	7.881268947688113
100000	0.048625	486.25	8.104166666666667
101000	0.045498	464.125098	7.665449333433354
102000	0.048622	505.863288	8.279957356747877
103000	0.044252	469.469468	7.616097168456069
104000	0.046216	499.872256	8.038063377379799
105000	0.048613	535.958325	8.543327638849044
106000	0.050011	561.923596	8.879993530847339
107000	0.048278	552.734822	8.660173044014099
108000	0.048894	570.299616	8.859751959628044
109000	0.045942	545.836902	8.408603283451444
110000	0.055833	675.5793	10.320789518982828
111000	0.048842	601.782282	9.117675602406222
112000	0.054398	682.368512	10.254248181229323
113000	0.050607	646.200783	9.632162969732776
114000	0.049657	645.342372	9.542207519706978
115000	0.059061	781.081725	11.457445214049848
116000	0.057351	771.715056	11.230800232085859
117000	0.060154	823.448106	11.889994440771717
118000	0.053544	745.546656	10.681708107835232
119000	0.05582	790.46702	11.238242244935636
120000	0.058234	838.5696	11.831241627293535
121000	0.054935	804.303335	11.261986844172828
122000	0.058031	863.733404	12.003439591578
123000	0.067678	1023.900462	14.123458523411818
124000	0.056122	862.931872	11.815257821673232
125000	0.057696	901.5	12.252971671271414
126000	0.058253	924.824628	12.478699185318818
127000	0.06815	1099.19135	14.724558798353353
128000	0.072979	1195.687936	15.902680591997171
129000	0.059539	990.788499	13.084014232744848
130000	0.062799	1061.3031	13.916522905199191

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133000	0.063918	1130.645502	14.519448147305 1
134000	0.061649	1106.969444	14.118279472576 2
135000	0.063338	1154.33505	14.622528610302 2
136000	0.064676	1196.247296	15.051426563844 8
137000	0.063776	1197.011744	14.960376750687 5
138000	0.061932	1179.433008	14.642857612634 1
139000	0.062627	1210.016267	14.923576905825 4
140000	0.065967	1292.9532	15.842149312714
141000	0.059827	1189.420587	14.478929597083 2
142000	0.067556	1362.199184	16.475218259275 4
143000	0.065903	1347.650447	16.194850618473 2
144000	0.068937	1429.477632	17.068897685643 4
145000	0.068982	1450.34655	17.208671897291 7
146000	0.073354	1563.613864	18.436195716649 6
147000	0.06921	1495.55889	17.523871604158 1
148000	0.075762	1659.490848	19.324328825366 5
149000	0.072853	1617.409453	18.718479580894 4
150000	0.072721	1636.2225	18.820526622489 4
151000	0.070189	1600.379389	18.296529718662 5
152000	0.074824	1728.733696	19.644797407635 2
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154000	0.074374	1763.853784	19.805255526029 9
155000	0.071366	1714.56815	19.138015951867 1
156000	0.07968	1939.09248	21.516984735837 9
157000	0.072902	1796.961398	19.823420601403 4
158000	0.071879	1794.387356	19.680178365001 7
159000	0.079239	2003.241159	21.844135856903 5
160000	0.07907	2024.192	21.946120908192 2
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165000	0.082017	2232.912825	23.535730935892 6
166000	0.078063	2151.104028	22.548183804775 8
167000	0.080307	2239.681923	23.347751835097
168000	0.0889	2509.1136	26.013679728144
169000	0.079432	2268.657352	23.393064315275 9
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172000	0.087646	2592.919264	26.308725905439 1
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174000	0.080364	2433.100464	24.426786987761
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176000	0.085768	2656.749568	26.393964988927 6
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178000	0.085078	2695.611352	26.503917155415 2
179000	0.085015	2723.965615	26.645420925582 4
180000	0.082932	2686.9968	26.149815563593 6
181000	0.090159	2953.698999	28.599631572108 4
182000	0.088281	2924.219844	28.171437973631 1
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195000	0.091965	3496.969125	31.622372147207
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197000	0.117383	4555.516847	40.810541606009 6
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199000	0.098483	3900.025283	34.615847519095 8
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204000	0.103798	4319.657568	37.476771464056 2
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206000	0.111466	4730.171176	40.672332619549 2
207000	0.111952	4797.031248	41.064212335906 9
208000	0.12367	5350.45888	45.599485889349 2
209000	0.116904	5106.483624	43.328931239729 7
210000	0.115115	5076.5715	42.886709187930 7
211000	0.117726	5241.279246	44.085388835377 1

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213000	0.208481	9458.574489	78.8714794754203
214000	0.110611	5065.541356	42.0583043823868
215000	0.104041	4809.295225	39.7601098029124
216000	0.108199	5048.132544	41.5571444229611
217000	0.105322	4959.507658	40.6547049410606
218000	0.106066	5040.680584	41.1459541220817
219000	0.108233	5190.962913	42.1948970153488
220000	0.108335	5243.414	42.4432331493041
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222000	0.106535	5250.47094	42.1484548458493
223000	0.106355	5288.927795	42.2822096357385
224000	0.112107	5625.080832	44.785085676157
225000	0.108873	5511.695625	43.7031125470754
226000	0.109027	5568.663052	43.9752593532176
227000	0.109088	5621.195552	44.2103799190176
228000	0.112197	5832.448848	45.6869604181971
229000	0.116924	6131.611484	47.8375965005327
230000	0.122754	6493.6866	50.4599713066586
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232000	0.117322	6314.739328	48.6805430921006
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234000	0.124389	6811.044084	52.0939685204164
235000	0.111641	6165.374225	46.9711253315972
236000	0.112586	6270.589856	47.5866207669562
237000	0.116341	6534.757629	49.3989841885298
238000	0.116587	6603.954028	49.7292255635929
239000	0.122548	7000.064308	52.5092485085763
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257000	0.134011	8851.292539	62.1075235940742
258000	0.128036	8522.588304	59.5878640978529
259000	0.125299	8405.182219	58.5582637363869
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265000	0.137075	9626.091875	65.6662428216734
266000	0.141368	10002.634208	67.9988804923771
267000	0.135755	9677.838195	65.5641672295028
268000	0.134699	9674.620976	65.3173466901323
269000	0.132697	9602.087617	64.6058948341867
270000	0.139123	10142.06677	68.0064858864982
271000	0.127895	9392.736695	62.7680812068932
272000	0.139255	10302.64192	68.6157076076362
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274000	0.134602	10105.379752	66.8497985814498
275000	0.146866	11106.74125	73.2281949127736
276000	0.136991	10435.426416	68.57271299763
277000	0.141858	10884.622482	71.2868082457149
278000	0.149492	11553.339728	75.415946069175
279000	0.159281	12398.592321	80.6664593284508
280000	0.14692	11518.528	74.6943360767146
281000	0.135882	10729.378602	69.3490308391124
282000	0.135812	10800.313488	69.5796677985125
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285000	0.141104	11461.1724	73.1215407670309
286000	0.137924	11281.631504	71.744418341147
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288000	0.149462	12396.976128	78.3332851205251
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300000	0.149411	13446.99	81.8342163788919
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317000	0.162289	16308.259321	94.3351219647066
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330000	0.168877	18390.7053	102.514508648723
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333000	0.171146	18978.208794	104.911010727432
334000	0.174176	19430.377856	107.114252525842
335000	0.170113	19090.931425	104.95348411064
336000	0.190748	21534.686208	118.063474422158
337000	0.169776	19281.290544	105.420215764987
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339000	0.181267	20831.384907	113.276026082442
340000	0.194265	22457.034	121.784911872844
341000	0.18513	21527.10153	116.426359000121
342000	0.17302	20237.11128	109.154680443161
343000	0.179608	21130.701592	113.668268488412
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345000	0.178263	21217.753575	113.52664821468
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347000	0.184319	22193.666471	118.117410665667
348000	0.183456	22217.255424	117.929771566186
349000	0.174241	21222.728041	112.353272793786
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352000	0.193208	23939.244032	125.738672684566
353000	0.195602	24373.769618	127.686669085638
354000	0.185128	23199.500448	121.218553355293
355000	0.180299	22722.181475	118.416240249585
356000	0.183516	23258.083776	120.895214542255
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366000	0.194216	26016.398496	131.823079182677
367000	0.185423	24974.438447	126.225622252292
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377000	0.232531	33049.398499	162.948476966758
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397000	0.230496	36328.244064	170.776010069603
398000	0.214882	34038.168328	159.639667189583
399000	0.212851	33886.092051	158.558966682036
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409000	0.216732	36255.145692	165.814055513446
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414000	0.220939	37868.060844	171.259992494634
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418000	0.229868	40163.456432	180.036577902443
419000	0.22802	40031.41922	179.049488065176
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430000	0.22673	41922.377	183.076270087144
431000	0.233716	43415.317876	189.189962683005
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434000	0.229447	43217.719132	187.127071996625
435000	0.225958	42756.90255	184.738954550829
436000	0.232376	44173.748096	190.456617406534
437000	0.227213	43390.639397	186.685046572888
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445000	0.227719	45094.054975	190.792102512184
446000	0.235862	46916.725592	198.092894875574
447000	0.245404	49033.927836	206.604602043594
448000	0.266989	53585.760256	225.318473808116
449000	0.236313	47640.937113	199.909660340701
450000	0.234189	47423.2725	198.58802780828
451000	0.23858	48527.41058	202.795673717307
452000	0.239148	48858.892992	203.76386699218
453000	0.241282	49513.237938	206.071917643087
454000	0.236408	48727.471328	202.389153356086

455000	0.279621	57888.537525	239.95165205294
456000	0.246202	51194.259072	211.773766253438
457000	0.26206	54730.96894	225.94653373379
458000	0.249056	52242.982784	215.240536906766
459000	0.363388	76558.947228	314.787522590318
460000	0.264478	55963.5448	229.643479423813
461000	0.248492	52809.768332	216.268064910746
462000	0.248706	53084.803464	216.95988886459
463000	0.251912	54002.123528	220.268829758704
464000	0.270012	58132.503552	236.64430792534
465000	0.249286	53901.86535	218.986584906189
466000	0.251418	54596.927208	221.370853562501
467000	0.281898	61478.852922	248.781655009662
468000	0.25079	54929.02896	221.838389368824
469000	0.28172	61967.41292	249.771079804702
470000	0.248763	54951.7467	221.057932444607
471000	0.253717	56284.832997	225.976669742562
472000	0.252685	56294.17504	225.571952004177
473000	0.253392	56691.138768	226.719055968075
474000	0.255855	57484.47798	229.443850282226
475000	0.254546	57431.941245	228.788444829632
476000	0.270181	61216.530256	243.391735156085
477000	0.248022	56432.197638	223.9352001796
478000	0.253819	57993.580396	229.686442346904
479000	0.244963	56204.555683	222.171700530154
480000	0.287304	66194.841603	261.158933194073
481000	0.258182	59733.245702	235.213422010705
482000	0.271979	63187.249196	248.337558366382
483000	0.262239	61177.474071	239.978970471004
484000	0.263721	61778.226576	241.87304738374
485000	0.269484	63389.3739	247.708322314155
486000	0.266427	62928.991692	245.441897492341
487000	0.258154	61226.126026	238.347272385936
488000	0.263992	62868.110848	244.276098305756
489000	0.264116	63155.682036	244.929912277716
490000	0.265118	63654.8318	246.400322709683
491000	0.273619	65964.342139	254.859773718486
492000	0.307636	74467.600704	287.17275372221
493000	0.295833	71901.914817	276.759022485525
494000	0.28281	69015.82116	265.153333900666
495000	0.267391	65517.479775	251.243219493428
496000	0.267397	65783.940352	251.795179356277
497000	0.277344	68506.464096	261.728527446533
498000	0.271564	67348.958256	256.828956613375
499000	0.266561	66373.955561	252.642266130472
500000	0.273855	68463.75	260.115238422907

Parallel Shell Sort

N	seconds
1000	0.000389
2000	0.000415
3000	0.00058
4000	0.000737
5000	0.000857
6000	0.00104
7000	0.001276
8000	0.001581
9000	0.001729
10000	0.010399
11000	0.003072
12000	0.003756
13000	0.002589
14000	0.013004
15000	0.006459
16000	0.022038
17000	0.003078
18000	0.006187
19000	0.003542
20000	0.019033
21000	0.004066
22000	0.010781
23000	0.009594
24000	0.004454
25000	0.014831
26000	0.013847
27000	0.009494
28000	0.009543
29000	0.013263
30000	0.012473
31000	0.019258
32000	0.015142
33000	0.016167
34000	0.012187
35000	0.016433
36000	0.023249
37000	0.019162
38000	0.022729
39000	0.020555
40000	0.014049
41000	0.025605
42000	0.021524
43000	0.013382
44000	0.025264
45000	0.014037
46000	0.016593
47000	0.018832
48000	0.025863
49000	0.022492
50000	0.028586
51000	0.019748

52000	0.016186
53000	0.02487
54000	0.027823
55000	0.019362
56000	0.027133
57000	0.029579
58000	0.027734
59000	0.028771
60000	0.017196
61000	0.031776
62000	0.022764
63000	0.027624
64000	0.029631
65000	0.02701
66000	0.035751
67000	0.028428
68000	0.028553
69000	0.032311
70000	0.016853
71000	0.035967
72000	0.021051
73000	0.030066
74000	0.024825
75000	0.030087
76000	0.032646
77000	0.030107
78000	0.039696
79000	0.040978
80000	0.026293
81000	0.042146
82000	0.047064
83000	0.023951
84000	0.046564
85000	0.043047
86000	0.04136
87000	0.024783
88000	0.038134
89000	0.034467
90000	0.037881
91000	0.03598
92000	0.038393
93000	0.047945
94000	0.025221
95000	0.045262
96000	0.044417
97000	0.03436
98000	0.040044
99000	0.045579
100000	0.030653
101000	0.039066
102000	0.040513
103000	0.043077
104000	0.044951
105000	0.043026
106000	0.030532
107000	0.049472
108000	0.04229
109000	0.04586
110000	0.042041
111000	0.049374
112000	0.046868
113000	0.042227
114000	0.04413
115000	0.061647
116000	0.049748
117000	0.050114
118000	0.042927
119000	0.050935
120000	0.033503
121000	0.052596
122000	0.047205
123000	0.059792
124000	0.04634
125000	0.048152
126000	0.048876
127000	0.051917
128000	0.05576
129000	0.03414
130000	0.062905
131000	0.049727
132000	0.048774
133000	0.050043
134000	0.053127
135000	0.051016
136000	0.052266
137000	0.054571
138000	0.055935
139000	0.053082
140000	0.05284
141000	0.057893
142000	0.058065
143000	0.054696
144000	0.053755
145000	0.056772
146000	0.050241
147000	0.061673
148000	0.055238
149000	0.060567
150000	0.057193
151000	0.053209
152000	0.054959
153000	0.058716
154000	0.051229
155000	0.057033
156000	0.058663
157000	0.055444
158000	0.060983
159000	0.057695
160000	0.060104
161000	0.057861
162000	0.061799
163000	0.063769
164000	0.075548
165000	0.06222
166000	0.060283
167000	0.061778
168000	0.065628
169000	0.064532
170000	0.066971
171000	0.06487
172000	0.062194
173000	0.062588
174000	0.064683
175000	0.061656
176000	0.060615
177000	0.066152
178000	0.060463
179000	0.068132
180000	0.071587

181000	0.065538
182000	0.064828
183000	0.064723
184000	0.066048
185000	0.065142
186000	0.06404
187000	0.065378
188000	0.067132
189000	0.07294
190000	0.064928
191000	0.068552
192000	0.070078
193000	0.068427
194000	0.068217
195000	0.06797
196000	0.067617
197000	0.087491
198000	0.073902
199000	0.070898
200000	0.072001
201000	0.073236
202000	0.072237
203000	0.071364
204000	0.078955
205000	0.068343
206000	0.070093
207000	0.071604
208000	0.072975
209000	0.074609
210000	0.073056
211000	0.074809
212000	0.084035
213000	0.10755
214000	0.076278
215000	0.079183
216000	0.077271
217000	0.074417
218000	0.086258
219000	0.093246
220000	0.090148
221000	0.092173
222000	0.096451
223000	0.094381
224000	0.106149
225000	0.091935
226000	0.094434
227000	0.094575
228000	0.082037
229000	0.088567
230000	0.1045
231000	0.085454
232000	0.083747
233000	0.082303
234000	0.084297
235000	0.082776
236000	0.082729
237000	0.092282
238000	0.094506
239000	0.081301
240000	0.085109
241000	0.083694
242000	0.085836
243000	0.084755
244000	0.083241
245000	0.086223
246000	0.092759
247000	0.086263
248000	0.084923
249000	0.086898
250000	0.095973
251000	0.085408
252000	0.085828
253000	0.087596
254000	0.094296
255000	0.090037
256000	0.107378
257000	0.088051
258000	0.087713
259000	0.086829
260000	0.087506
261000	0.08983
262000	0.095719
263000	0.10183
264000	0.097576
265000	0.093699
266000	0.091548
267000	0.088184
268000	0.102246
269000	0.091868
270000	0.09806
271000	0.111903
272000	0.117624
273000	0.106923
274000	0.118846
275000	0.115344
276000	0.152048
277000	0.076307
278000	0.073198
279000	0.076454
280000	0.118312
281000	0.076543
282000	0.203614
283000	0.144544
284000	0.148324
285000	0.16694
286000	0.13722
287000	0.193602
288000	0.190315
289000	0.131666
290000	0.072401
291000	0.073376
292000	0.089261
293000	0.111095
294000	0.089961
295000	0.236863
296000	0.126458
297000	0.096603
298000	0.145922
299000	0.108008
300000	0.117869
301000	0.0812
302000	0.079033
303000	0.073422
304000	0.07433
305000	0.128554
306000	0.07822
307000	0.084975
308000	0.077739
309000	0.080906

310000	0.124078
311000	0.115567
312000	0.112106
313000	0.128767
314000	0.107911
315000	0.100555
316000	0.089376
317000	0.110488
318000	0.105373
319000	0.085629
320000	0.124442
321000	0.163947
322000	0.130849
323000	0.13405
324000	0.183744
325000	0.221341
326000	0.189959
327000	0.186893
328000	0.214917
329000	0.168981
330000	0.178678
331000	0.166992
332000	0.103028
333000	0.194586
334000	0.147228
335000	0.108762
336000	0.099914
337000	0.177929
338000	0.192512
339000	0.189228
340000	0.225392
341000	0.114983
342000	0.118587
343000	0.099776
344000	0.146596
345000	0.199507
346000	0.139915
347000	0.112031
348000	0.126221
349000	0.10797
350000	0.160806
351000	0.167435
352000	0.093858
353000	0.09693
354000	0.166787
355000	0.126496
356000	0.111708
357000	0.106801
358000	0.109895
359000	0.098493
360000	0.09568
361000	0.10844
362000	0.129277
363000	0.12067
364000	0.108484
365000	0.091243
366000	0.101391
367000	0.158953
368000	0.133432
369000	0.110675
370000	0.097465
371000	0.15191
372000	0.151617
373000	0.112021
374000	0.099029
375000	0.145203
376000	0.177966
377000	0.137989
378000	0.137488
379000	0.173413
380000	0.2999
381000	0.258115
382000	0.20834
383000	0.253816
384000	0.155175
385000	0.248074
386000	0.125904
387000	0.098869
388000	0.110466
389000	0.103593
390000	0.124218
391000	0.136448
392000	0.122596
393000	0.119975
394000	0.233233
395000	0.196707
396000	0.151998
397000	0.153662
398000	0.12474
399000	0.221359
400000	0.168603
401000	0.110131
402000	0.169159
403000	0.126872
404000	0.131607
405000	0.146415
406000	0.159927
407000	0.127939
408000	0.108105
409000	0.112135
410000	0.239431
411000	0.152836
412000	0.113153
413000	0.112565
414000	0.128948
415000	0.194461
416000	0.161066
417000	0.155463
418000	0.177388
419000	0.170809
420000	0.129476
421000	0.21128
422000	0.154301
423000	0.165122
424000	0.188745
425000	0.114517
426000	0.201215
427000	0.123931
428000	0.114358
429000	0.111293
430000	0.127082
431000	0.143121
432000	0.149902
433000	0.210839
434000	0.187444
435000	0.171838
436000	0.136655
437000	0.119013
438000	0.12028

439000	**0.132762**
440000	**0.131144**
441000	**0.116877**
442000	**0.146484**
443000	**0.14271**
444000	**0.187453**
445000	**0.130218**
446000	**0.119819**
447000	**0.210177**
448000	**0.129145**
449000	**0.17983**
450000	**0.121614**
451000	**0.124852**
452000	**0.146418**
453000	**0.147426**
454000	**0.128799**
455000	**0.134063**
456000	**0.150622**
457000	**0.154793**
458000	**0.179628**
459000	**0.263451**
460000	**0.224888**
461000	**0.130346**
462000	**0.167942**
463000	**0.171465**
464000	**0.129397**
465000	**0.201904**
466000	**0.164156**
467000	**0.144759**
468000	**0.130795**
469000	**0.156003**
470000	**0.125469**
471000	**0.128497**
472000	**0.136509**
473000	**0.13216**
474000	**0.12823**
475000	**0.129359**
476000	**0.145404**
477000	**0.303629**
478000	**0.293367**
479000	**0.297533**
480000	**0.268907**
481000	**0.288066**
482000	**0.317322**
483000	**0.166057**
484000	**0.142119**
485000	**0.134682**
486000	**0.129162**
487000	**0.147734**
488000	**0.194193**
489000	**0.280181**
490000	**0.205079**
491000	**0.29307**
492000	**0.257408**
493000	**0.153549**
494000	**0.347886**
495000	**0.148087**
496000	**0.274171**
497000	**0.314713**
498000	**0.224578**
499000	**0.281467**
500000	**0.194552**

Merge Sort

N	seconds	theo_seconds
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2000	0.000412	0.000906682905475707
3000	0.000643	0.00223578896678474
4000	0.000968	0.00464905876214062
5000	0.001359	0.00837816705982108
6000	0.001223	0.00924135795843839
7000	0.001532	0.0137449437937043
8000	0.001613	0.016788491064048
9000	0.001877	0.0222663395706528
10000	0.002935	0.0391333333333333
11000	0.002431	0.0360236272646054
12000	0.005035	0.0821547102953992
13000	0.003061	0.0545687159394486
14000	0.004274	0.082695905714281
15000	0.003618	0.0755454908763173
16000	0.010336	0.231753515417235
17000	0.003822	0.0916230627392107
18000	0.004596	0.117343394600729
19000	0.005404	0.146441768243811
20000	0.00522	0.149675843849107
21000	0.012038	0.364216131090048
22000	0.005066	0.161323897540999
23000	0.0071	0.237423385207224
24000	0.013852	0.485397488961513
25000	0.007075	0.259295213011289
26000	0.008983	0.343717448401789
27000	0.013927	0.55544042829098
28000	0.007652	0.31761009705442
29000	0.008439	0.364029041474603
30000	0.013978	0.625812008984714
31000	0.007077	0.328448789308406
32000	0.008867	0.426103091816134
33000	0.016343	0.812306806513667
34000	0.009193	0.472122704422854
35000	0.010269	0.544402072053385
36000	0.015722	0.859610255004759
37000	0.01946	1.09639886845424
38000	0.010742	0.623149781668198
39000	0.018318	1.09328857912965
40000	0.01063	0.652265302770883
41000	0.012506	0.788395490465872
42000	0.015974	1.03392497830742
43000	0.018895	1.25487453937719
44000	0.011134	0.758269630799959
45000	0.023345	1.62943869201128
46000	0.01111	0.794316339153062
47000	0.01412	1.03353034081349
48000	0.012927	0.968230487608867
49000	0.014556	1.11508473763462
50000	0.014799	1.15900095156948
51000	0.01474	1.17962293472662
52000	0.016746	1.36888599453681
53000	0.014803	1.23549105065938
54000	0.015375	1.30968997303101
55000	0.014847	1.29030302226689
56000	0.016562	1.4679371485945
57000	0.015161	1.36997255505016
58000	0.019291	1.77656492886057
59000	0.014538	1.36405338205665
60000	0.019525	1.86586806327481
61000	0.015801	1.5374642667011
62000	0.01829	1.81149210935241

63000	0.019492	1.96452366578893
64000	0.017117	1.75503749577989
65000	0.017547	1.82979746449526
66000	0.019247	2.04075876680224
67000	0.019138	2.06273837048797
68000	0.017415	1.90758456820166
69000	0.023245	2.58701808362631
70000	0.020729	2.3434608696673
71000	0.018951	2.17582332820895
72000	0.021149	2.4654653992086
73000	0.019026	2.25155313125853
74000	0.020694	2.48550906980012
75000	0.020024	2.44045566845388
76000	0.021898	2.70762808644204
77000	0.024616	3.08733696273171
78000	0.020309	2.58319228143706
79000	0.022649	2.92106070775345
80000	0.024141	3.15641321002593
81000	0.021392	2.83506241114401
82000	0.032597	4.37813279732816
83000	0.022216	3.02347527623961
84000	0.025362	3.49690799508684
85000	0.025181	3.51695144243833
86000	0.024052	3.40229062681356
87000	0.024354	3.48861450446994
88000	0.025355	3.67744250580278
89000	0.031715	4.65677382046872
90000	0.024385	3.62427610778034
91000	0.028063	4.22135588397877
92000	0.02712	4.12828306024675
93000	0.026699	4.11225931354669
94000	0.028388	4.42355080991696
95000	0.026758	4.21780772729344
96000	0.026984	4.30213142247487
97000	0.026644	4.29605065683854
98000	0.029107	4.74580083458259
99000	0.028817	4.75065424028968
100000	0.031104	5.184
101000	0.03717	6.26235772393786
102000	0.039924	6.79875401075238
103000	0.033759	5.81017410082955
104000	0.032294	5.61669592152291
105000	0.031726	5.57557880958025

106000	0.032691	5.80464034946176
107000	0.031742	5.69392296207579
108000	0.031379	5.6859769448433
109000	0.033619	6.15316777211166
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113000	0.044802	8.5272821026729
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117000	0.03234	6.39230009998596
118000	0.039335	7.84709749779053
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124000	0.051096	10.7571436095687
125000	0.047976	10.1887231160031
126000	0.053299	11.4174752867373
127000	0.050911	10.9998828023913
128000	0.043247	9.42385107444742
129000	0.039219	8.61858536747373
130000	0.041501	9.19679639944373
131000	0.039006	8.71605374158123
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133000	0.040175	9.1260494589628
134000	0.040947	9.37730035464609
135000	0.037627	8.68675809182227
136000	0.038908	9.05468651039136
137000	0.03956	9.27986239740964
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139000	0.041076	9.78812405166599
140000	0.043762	10.509559904543
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144000	0.052884	13.0941524175343
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170000	0.051227	15.1832783907419
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173000	0.048338	14.601008116072
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250000	0.081603	36.707341543972
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256000	0.083673	38.6153525433633
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276000	0.079419	39.7542633717454
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319000	0.091829	53.741674229464
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342000	0.099516	62.7825521846122
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388000	0.115551	83.5228322509883
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395000	0.112642	83.0042321893315
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424000	0.120935	96.1837625678753
425000	0.123582	98.5387377734093
426000	0.120961	96.6933400614231
427000	0.128199	102.738366761731
428000	0.122458	98.3851219920563
429000	0.123048	99.1079524990907
430000	0.122613	99.0055603766371
431000	0.124039	100.407904384968
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433000	0.123643	100.5876713985
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435000	0.124921	102.133028887864
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440000	0.131628	108.949337038743
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443000	0.127885	106.628673617973
444000	0.13211	110.419213098913
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446000	0.179767	150.980511625854
447000	0.133573	112.454550491308
448000	0.130643	110.252787095025
449000	0.127944	108.234593876048

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457000	0.133583	115.174447896515
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459000	0.132289	114.596317368627
460000	0.134162	116.491460486156
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467000	0.133873	118.146090079066
468000	0.134362	118.851029436476
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492000	0.14145	132.041068060977
493000	0.14173	132.591888859166
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495000	0.142512	133.905680058219
496000	0.141548	133.289094670181
497000	0.14282	134.778716287044
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Parallel Merge Sort

N	seconds
1000	**0.000596**
2000	**0.001475**
3000	**0.001011**
4000	**0.001406**
5000	**0.000998**
6000	**0.001313**
7000	**0.003835**
8000	**0.00897**
9000	**0.002388**
10000	**0.007431**
11000	**0.005484**
12000	**0.002125**
13000	**0.002946**
14000	**0.007632**
15000	**0.013331**
16000	**0.004358**
17000	**0.00451**
18000	**0.005276**
19000	**0.026661**
20000	**0.014718**
21000	**0.010834**
22000	**0.007978**
23000	**0.025624**
24000	**0.009047**
25000	**0.004263**
26000	**0.01112**
27000	**0.026003**
28000	**0.005885**
29000	**0.010418**
30000	**0.018528**
31000	**0.005243**
32000	**0.016531**
33000	**0.00534**
34000	**0.012576**
35000	**0.018985**
36000	**0.00806**
37000	**0.018005**
38000	**0.016759**
39000	**0.017794**
40000	**0.006812**
41000	**0.027205**
42000	**0.014734**
43000	**0.021**
44000	**0.023532**
45000	**0.010758**
46000	**0.025274**
47000	**0.01885**
48000	**0.013571**
49000	**0.02405**
50000	**0.010234**
51000	**0.022093**
52000	**0.015186**
53000	**0.02119**
54000	**0.024997**
55000	**0.014843**
56000	**0.017679**
57000	**0.029648**
58000	**0.019346**
59000	**0.027069**
60000	**0.028481**
61000	**0.031019**
62000	**0.026292**
63000	**0.024686**
64000	**0.017963**
65000	**0.024435**
66000	**0.019532**
67000	**0.023266**
68000	**0.023749**
69000	**0.02731**
70000	**0.024213**
71000	**0.019727**
72000	**0.023804**
73000	**0.033209**

74000	0.023602
75000	0.031424
76000	0.025285
77000	0.020827
78000	0.029656
79000	0.025683
80000	0.030991
81000	0.033872
82000	0.031874
83000	0.023075
84000	0.038865
85000	0.033135
86000	0.026931
87000	0.033294
88000	0.028439
89000	0.034739
90000	0.033413
91000	0.035377
92000	0.030067
93000	0.030057
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