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Program Structures & Algorithms Spring 2023 Assignment No. 6

TASK:

In this assignment, your task is to determine--for sorting algorithms--what is the best predictor of total execution time: comparisons, swaps/copies, hits (array accesses), or something else.

ANSWER:

To identify the best predictor, following analysis has been done (note: all data is given in the respective csv files under assignment 6 folder in github):

Merge Sort:

MERGE SORT:

No of elements	With instrumentation (millisec)	Without instrumentation (Millisec)	Hits	Copies	Swaps	Compares
10000	16.6111254	11.8157998	259091.2	9772.8	0	121506.6
20000	28.50805	9.4597916	558159.2	19539.8	0	263064.4
40000	21.525225	18.363867	1196199.2	39049.8	0	565954.6
80000	37.0881834	26.6034668	2552395.2	78098.8	0	1212045.6
160000	68.7268502	71.8383	5424253.6	156063.4	0	2584144.4

Heap Sort:

HEAP SORT:

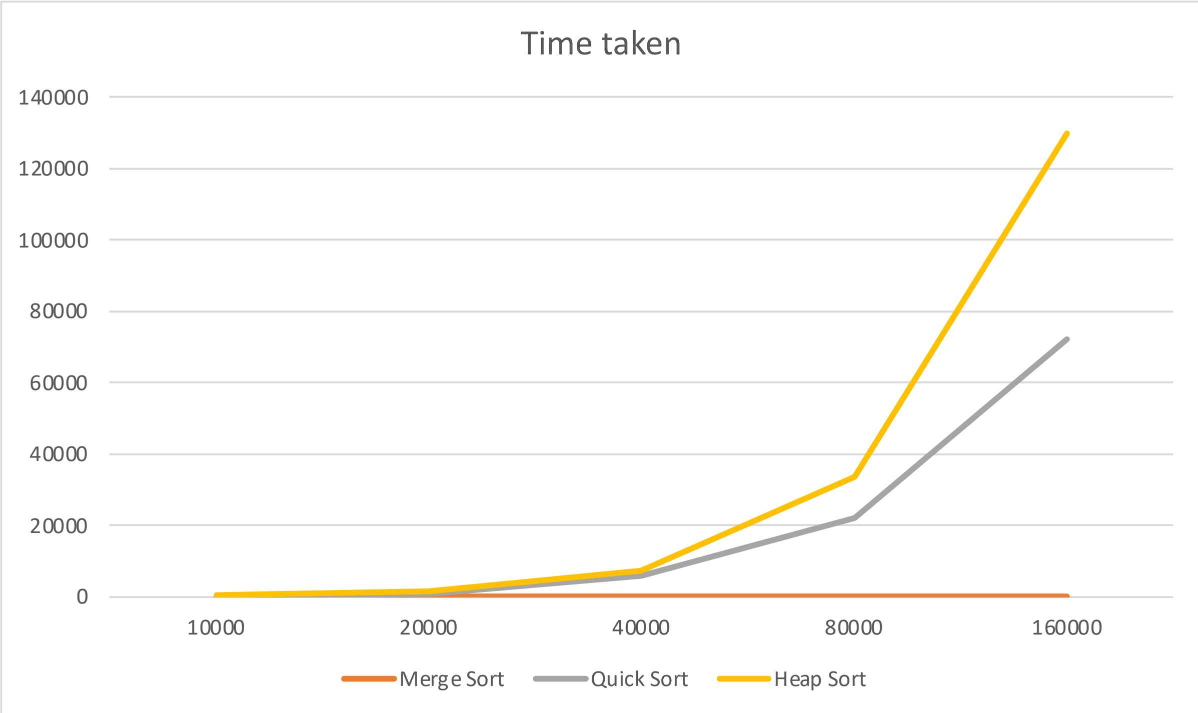
No of elements	With instrumentation (millisec)	Without instrumentation (Millisec)	Hits	Copies	Swaps	Compares
10000	386.37055	11.1339666	967718.4	0	124223.6	235412
20000	1738.65645	11.7096002	2095556.4	0	268464.6	510849
40000	7240.264483	22.5612584	4509526	0	576670.6	1101421.8
80000	33774.65812	43.9586748	9661624.4	0	1233814.6	2363183
160000	129859.9997	128.5296998	20600000	0	2627287	5046041

Quick Sort:

QUICK SORT:

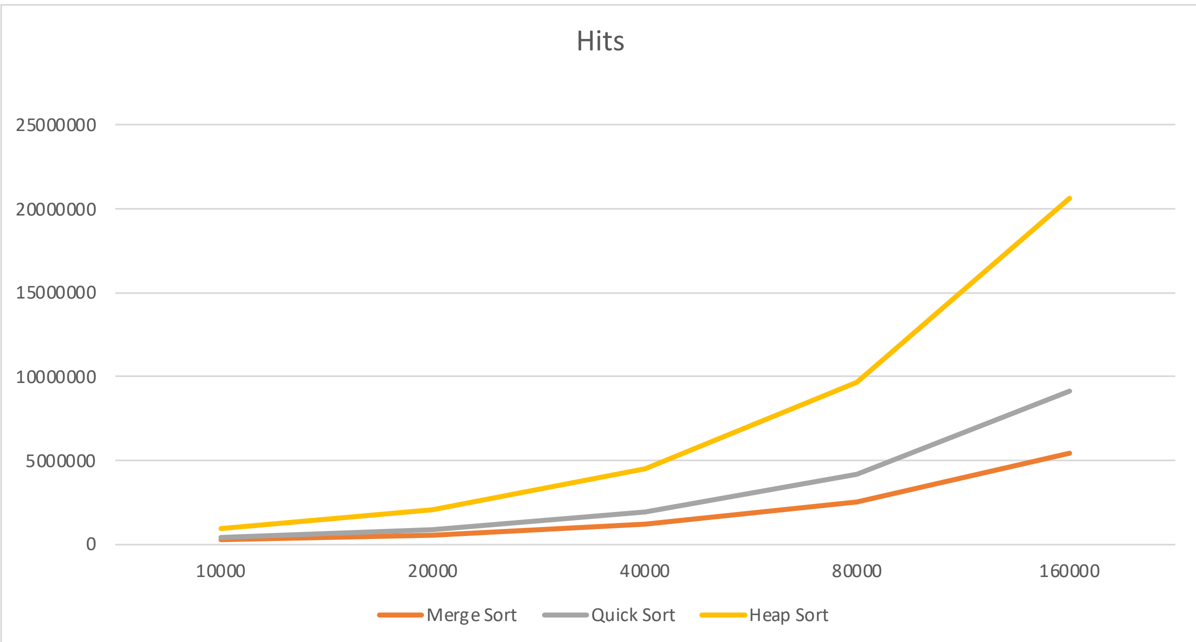
No of elements	With instrumentation (millisec)	Without instrumentation (Millisec)	Hits	Copies	Swaps	Compares
10000	263.4287416	3.9055504	411597.8	0	64000.2	159316.8
20000	930.1212252	13.5422256	858028.4	0	132866.4	333794
40000	6021.12425	52.1592748	1936224.2	0	301206	746156.4
80000	22058.78133	22.658675	4157034.2	0	648538.8	1592240
160000	72146.56801	49.13245	9121877.8	0	1437622.8	3430107.2

Comparing all the runtimes, we get the following graphs:



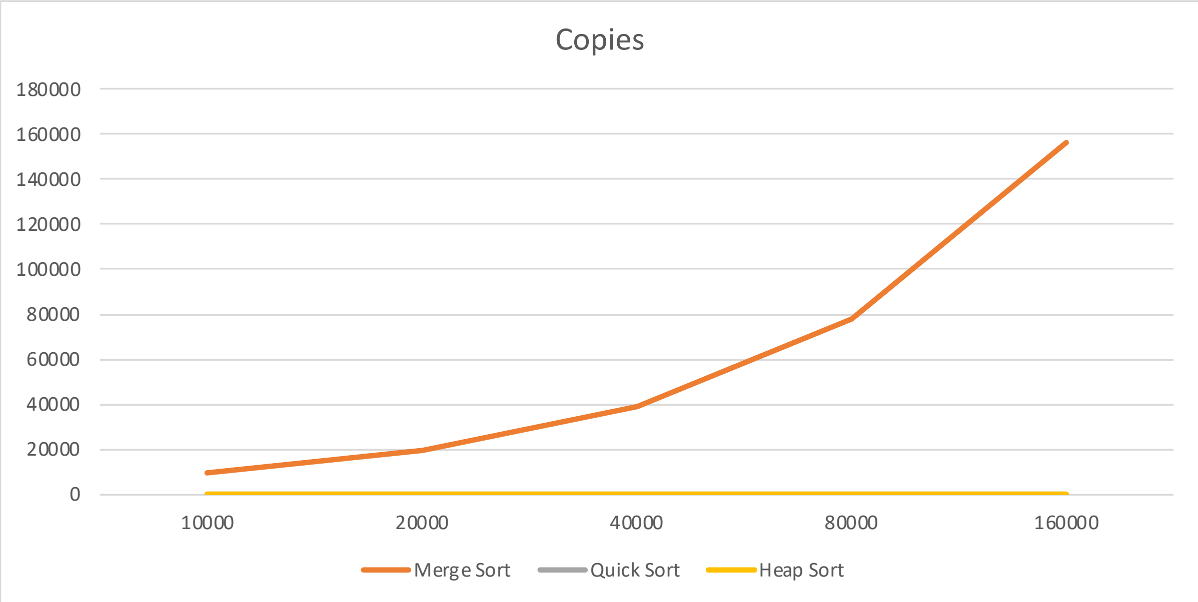
Looking at the above graph, we notice that time increases for every algorithm as the input size increases. For merge sort, it is a straight graph while for quick sort and heap sort, it is predominant as the input size increases.

Comparing all the hits (array accesses):



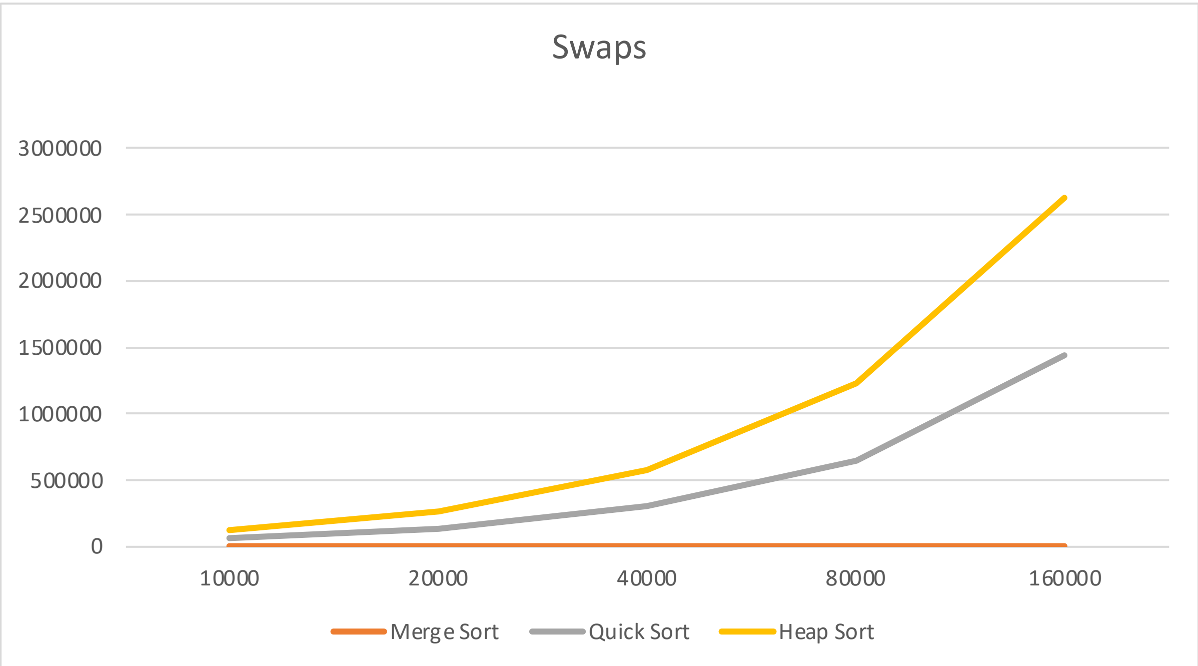
We can see that the effect of hits is high for heap sort as the input size increases, while for quick sort it seems to perform better compared to merge sort for smaller input size but merge sort comes out better for larger input sizes.

Comparing all the copies:



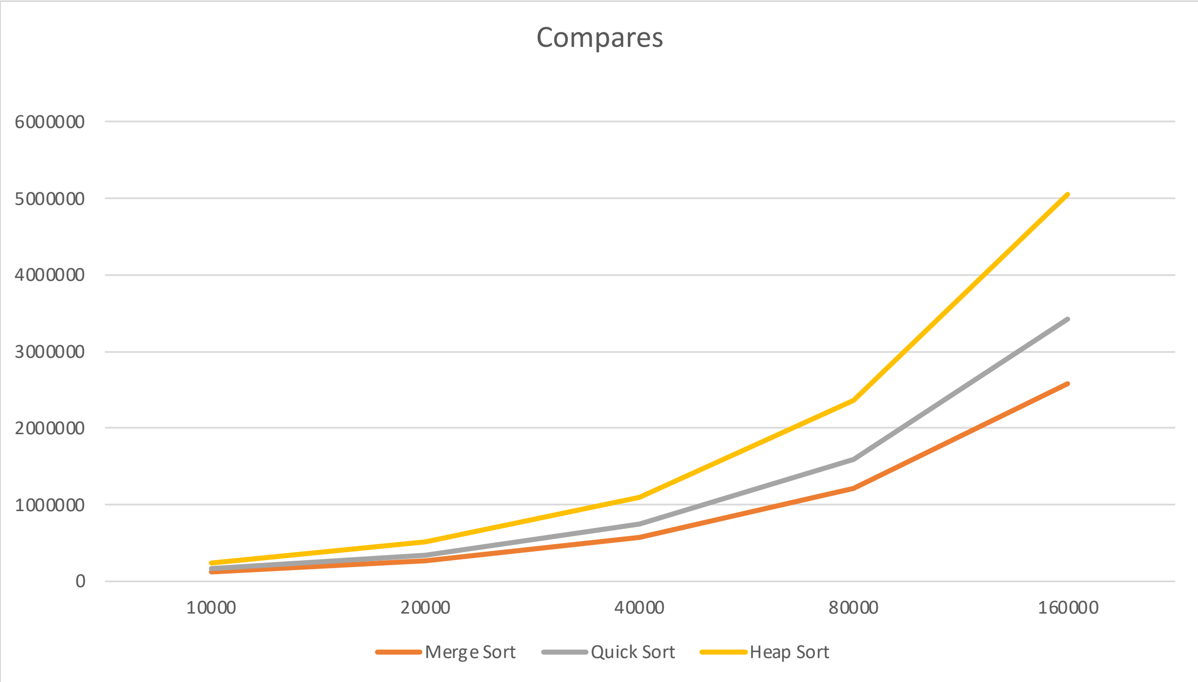
Copies are only used in merge sort, while quick sort and heap sort uses swaps. So only merge sort number of copies increase while input size increases.

Comparing all the swaps:



As the number of elements increases, there is a linear increase in the number of swaps required for sorting using comparison-based algorithms. Merge sort, being a non-comparison based algorithm, does not involve any swaps and therefore its swap count is 0. Among the comparison-based algorithms, heap sort requires the highest number of swaps, while quick sort requires a relatively lower number of swaps compared to heap sort.

Comparing all the compares:



We can see that the number of compares is the highest for heap sort followed by quick sort and least for merge sort.

<u>CONCLUSION:</u>

Based on the above analysis, the following conclusion can be arrived at:

The quantity of comparisons and swaps/copies is typically a reliable indicator of the overall execution time for quick sort. Quick sort employs a divide-and-conquer strategy and heavily relies on comparisons to establish an element's proper place in the sorted sequence. A lot of swaps and duplicates are also carried out by quick sort in order to shift items into their final placements.

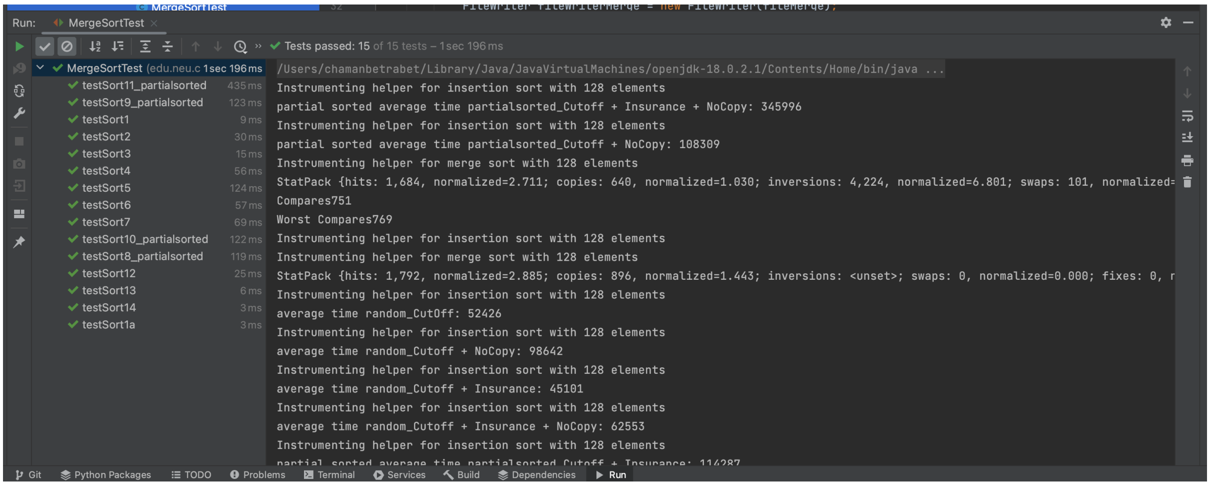
The amount of swaps/copies is probably the best indicator of the overall execution time for heap sort. Building a heap data structure and continually exchanging the root element with the last element in the heap until the heap is sorted are both steps in the heap sort process. This method requires a large number of swaps and copies, which may slow down execution.

The number of comparisons is frequently the most accurate indicator of the overall execution time for merge sort. Recursively sorting the input data into smaller subarrays, merging them back together, and repeating this process is known as merge sort. The algorithm analyses elements from the two subarrays to ascertain their relative order during the merging phase. In contrast to quick sort and heap sort, merge sort doesn't include any swaps or copies, which can lead to quicker execution speeds.

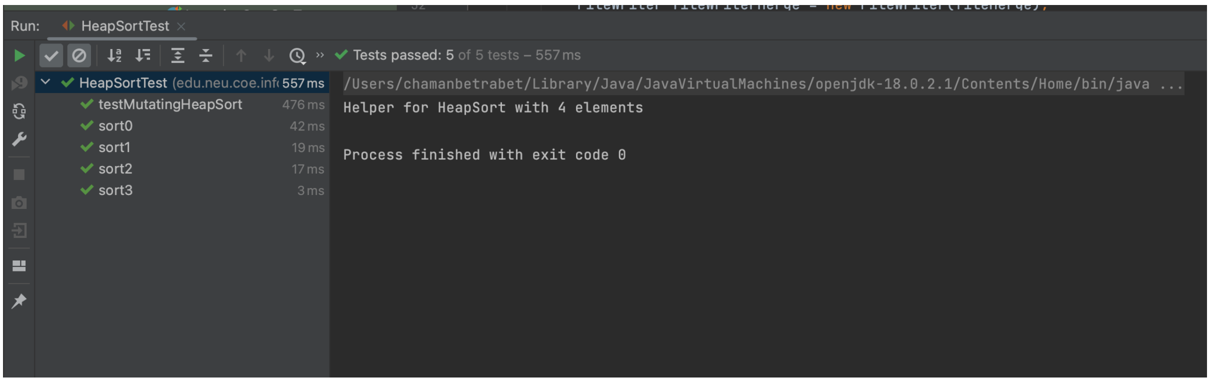
From the factors taken into account, array hits are also involved in compares, copies, and swaps. As a result, array hits happen every time a compare, copy, or swap happens. This suggests that comparing hits would be a fair technique to decide which algorithm is inherently superior. If the other operations being done in the algorithms being compared take precisely the same amount of time, then a higher number of hits would imply a worse algorithm's performance. The best time predictor in this case would be hits.

TEST CASE RESULTS:

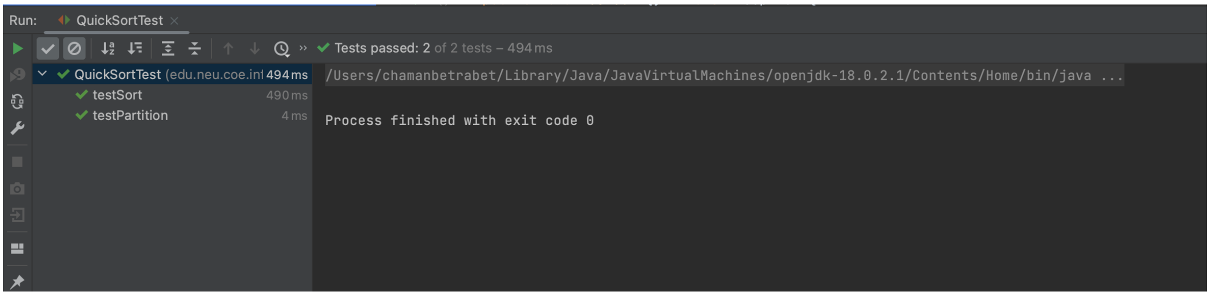
Merge Sort:



Heap Sort:



Quick Sort:


Run: QuickSortTest
Tests passed: 2 of 2 tests – 494 ms
QuickSortTest (edu.neu.coe.inf 494 ms
testSort 490 ms
testPartition 4 ms
/Users/chamanbetrabet/Library/Java/JavaVirtualMachines/openjdk-18.0.2.1/Contents/Home/bin/java ...
Process finished with exit code 0