NAME: Uday Kiran Reddy Mulpuri.   **NUID: 002781063**
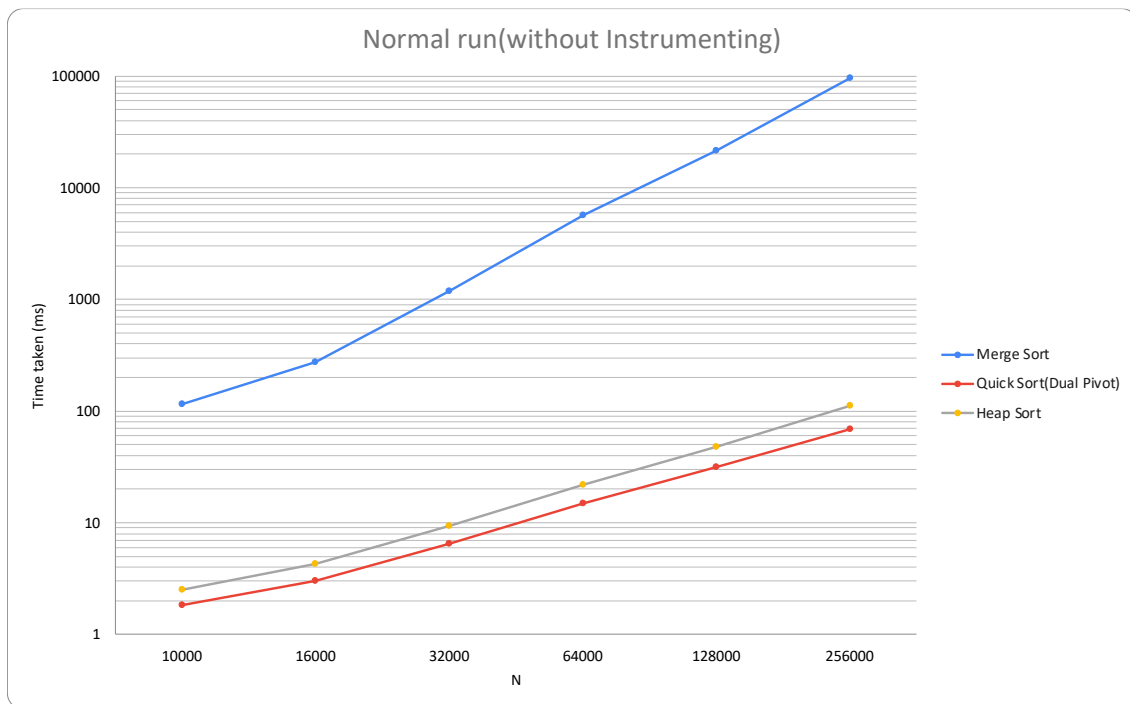
Task: Assignment 6 –
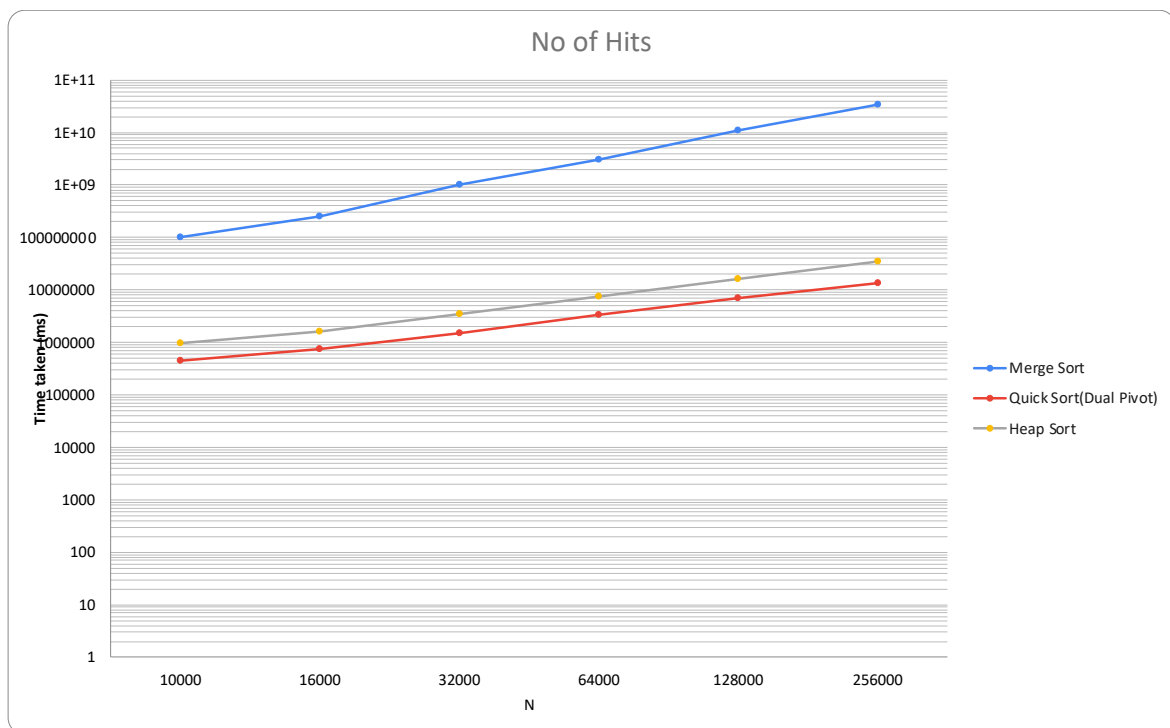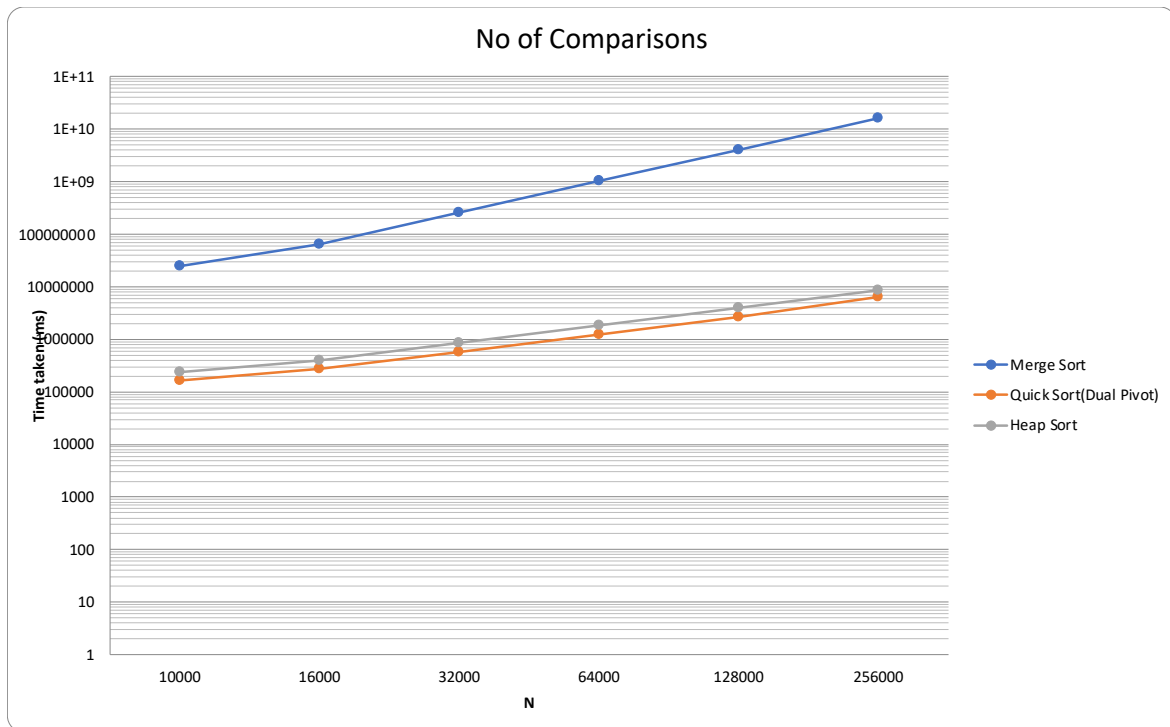## Hits as time predictor

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.
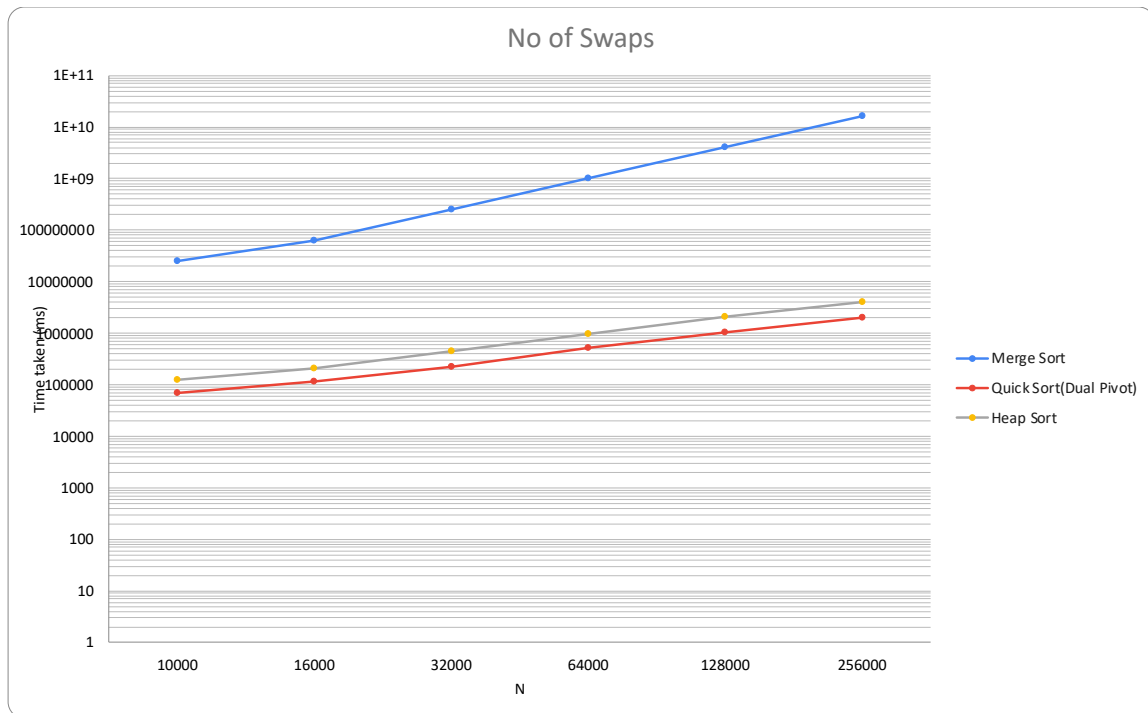
Conclusion

In this scenario, all three factors may be good predictors of the total execution time.

Based on the below graphs from the experiments, it appears that there is a strong correlation between the number of comparisons, hits, and swaps and the total execution time for Merge Sort, Quick Sort and Heap Sort.

No of Comparisons

Time taken(ms) vs N

- Merge Sort
- Quick Sort(Dual Pivot)
- Heap Sort

No of Hits

Time taken(ms) vs N

- Merge Sort
- Quick Sort(Dual Pivot)
- Heap Sort

No of Swaps

Screenshots of some runs

Quick Sort without Instrument

```
2023-03-12 12:30:22 INFO  SortBenchmarkHelper - Testing with words: 81,546 from eng-uk_web_2002_100K-sentences.txt
2023-03-12 12:30:22 INFO  SortBenchmark - Testing pure sorts with 108 runs of sorting 64,000 words
2023-03-12 12:30:22 INFO  SorterBenchmark - run: sort 64,000 elements using SorterBenchmark on class java.lang.String from 81,546 total elements and 108 runs using sorter
2023-03-12 12:30:22 INFO  Benchmark_Timer - Begin run: Helper for QuickSort basic with 64000 elements with 108 runs
2023-03-12 12:30:24 INFO  TimeLogger - Raw time per run (mSec): 15.06
2023-03-12 12:30:24 INFO  TimeLogger - Normalized time per run (n log n): 2.70
2023-03-12 12:30:25 INFO  SortBenchmarkHelper - Testing with words: 81,546 from eng-uk_web_2002_100K-sentences.txt
2023-03-12 12:30:25 INFO  SortBenchmark - Testing pure sorts with 50 runs of sorting 128,000 words
2023-03-12 12:30:25 INFO  SorterBenchmark - run: sort 128,000 elements using SorterBenchmark on class java.lang.String from 81,546 total elements and 50 runs using sorter
2023-03-12 12:30:25 INFO  Benchmark_Timer - Begin run: Helper for QuickSort basic with 128000 elements with 50 runs
2023-03-12 12:30:27 INFO  TimeLogger - Raw time per run (mSec): 31.51
2023-03-12 12:30:27 INFO  TimeLogger - Normalized time per run (n log n): 2.64
2023-03-12 12:30:27 INFO  SortBenchmarkHelper - Testing with words: 303,172 from eng-uk_web_2002_1M-sentences.txt
2023-03-12 12:30:27 INFO  SortBenchmark - Testing pure sorts with 24 runs of sorting 256,000 words
2023-03-12 12:30:27 INFO  SorterBenchmark - run: sort 256,000 elements using SorterBenchmark on class java.lang.String from 303,172 total elements and 24 runs using sorte
2023-03-12 12:30:27 INFO  Benchmark_Timer - Begin run: Helper for QuickSort basic with 256000 elements with 24 runs
2023-03-12 12:30:29 INFO  TimeLogger - Raw time per run (mSec): 68.70
2023-03-12 12:30:29 INFO  TimeLogger - Normalized time per run (n log n): 2.71
2023-03-12 12:30:29 INFO  SortBenchmark - Beginning LocalDateTime sorts

Process finished with exit code 0
```

Heap Sort without instrument

```
/Library/Java/JavaVirtualMachines/jdk-17.0.5.jdk/Contents/Home/bin/java ...
2023-03-12 12:28:19 INFO  SortBenchmark - SortBenchmark.main: null with word counts: [10000, 16000, 32000, 64000, 128000, 256000]
2023-03-12 12:28:19 INFO  Benchmark_Timer - Begin run: intArraysorter with 100 runs
2023-03-12 12:28:20 INFO  TimeLogger - Raw time per run (mSec): 4.00
2023-03-12 12:28:20 INFO  TimeLogger - Normalized time per run (n log n): .44
2023-03-12 12:28:20 INFO  Benchmark_Timer - Begin run: integerArraysorter with 100 runs
2023-03-12 12:28:21 INFO  TimeLogger - Raw time per run (mSec): 12.70
2023-03-12 12:28:21 INFO  TimeLogger - Normalized time per run (n log n): 1.40
2023-03-12 12:28:21 INFO  SortBenchmark - Beginning String sorts
2023-03-12 12:28:21 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 12:28:21 INFO  SortBenchmark - Testing pure sorts with 844 runs of sorting 10,000 words
2023-03-12 12:28:21 INFO  SorterBenchmark - run: sort 10,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 844 runs using sorter
2023-03-12 12:28:21 INFO  Benchmark_Timer - Begin run: Helper for Heapsort with 10000 elements with 844 runs
2023-03-12 12:28:24 INFO  TimeLogger - Raw time per run (mSec): 2.53
2023-03-12 12:28:24 INFO  TimeLogger - Normalized time per run (n log n): 3.56
2023-03-12 12:28:24 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 12:28:24 INFO  SortBenchmark - Testing pure sorts with 499 runs of sorting 16,000 words
2023-03-12 12:28:24 INFO  SorterBenchmark - run: sort 16,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 499 runs using sorter
2023-03-12 12:28:24 INFO  Benchmark_Timer - Begin run: Helper for Heapsort with 16000 elements with 499 runs
2023-03-12 12:28:26 INFO  TimeLogger - Raw time per run (mSec): 4.28
2023-03-12 12:28:26 INFO  TimeLogger - Normalized time per run (n log n): 3.56
2023-03-12 12:28:26 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 12:28:26 INFO  SortBenchmark - Testing pure sorts with 231 runs of sorting 32,000 words
2023-03-12 12:28:26 INFO  SorterBenchmark - run: sort 32,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 231 runs using sorter
2023-03-12 12:28:26 INFO  Benchmark_Timer - Begin run: Helper for Heapsort with 32000 elements with 231 runs
2023-03-12 12:28:29 INFO  TimeLogger - Raw time per run (mSec): 9.40
2023-03-12 12:28:29 INFO  TimeLogger - Normalized time per run (n log n): 3.62
2023-03-12 12:28:29 INFO  SortBenchmarkHelper - Testing with words: 81,546 from eng-uk_web_2002_100K-sentences.txt
2023-03-12 12:28:29 INFO  SortBenchmark - Testing pure sorts with 108 runs of sorting 64,000 words
```

```
2023-03-12 12:28:29 INFO  SortBenchmarkHelper - Testing with words: 81,546 from eng-uk_web_2002_100K-sentences.txt
2023-03-12 12:28:29 INFO  SortBenchmark - Testing pure sorts with 108 runs of sorting 64,000 words
2023-03-12 12:28:29 INFO  SorterBenchmark - run: sort 64,000 elements using SorterBenchmark on class java.lang.String from 81,546 total elements and 108 runs using sorte
2023-03-12 12:28:29 INFO  Benchmark_Timer - Begin run: Helper for Heapsort with 64000 elements with 108 runs
2023-03-12 12:28:32 INFO  TimeLogger - Raw time per run (mSec): 21.92
2023-03-12 12:28:32 INFO  TimeLogger - Normalized time per run (n log n): 3.93
2023-03-12 12:28:32 INFO  SortBenchmarkHelper - Testing with words: 81,546 from eng-uk_web_2002_100K-sentences.txt
2023-03-12 12:28:32 INFO  SortBenchmark - Testing pure sorts with 50 runs of sorting 128,000 words
2023-03-12 12:28:32 INFO  SorterBenchmark - run: sort 128,000 elements using SorterBenchmark on class java.lang.String from 81,546 total elements and 50 runs using sorte
2023-03-12 12:28:32 INFO  Benchmark_Timer - Begin run: Helper for Heapsort with 128000 elements with 50 runs
2023-03-12 12:28:35 INFO  TimeLogger - Raw time per run (mSec): 47.76
2023-03-12 12:28:35 INFO  TimeLogger - Normalized time per run (n log n): 4.01
2023-03-12 12:28:36 INFO  SortBenchmarkHelper - Testing with words: 303,172 from eng-uk_web_2002_1M-sentences.txt
2023-03-12 12:28:36 INFO  SortBenchmark - Testing pure sorts with 24 runs of sorting 256,000 words
2023-03-12 12:28:36 INFO  SorterBenchmark - run: sort 256,000 elements using SorterBenchmark on class java.lang.String from 303,172 total elements and 24 runs using sort
2023-03-12 12:28:36 INFO  Benchmark_Timer - Begin run: Helper for Heapsort with 256000 elements with 24 runs
2023-03-12 12:28:39 INFO  TimeLogger - Raw time per run (mSec): 111.88
2023-03-12 12:28:39 INFO  TimeLogger - Normalized time per run (n log n): 4.41
2023-03-12 12:28:39 INFO  SortBenchmark - Beginning LocalDateTime sorts

Process finished with exit code 0
```

Merge Sort without Instrument

Merge Sort with Instrumenting

```
2023-03-12 22:05:55 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 22:05:55 INFO  SortBenchmark - Testing with 1 runs of sorting 16,000 words and instrumented
2023-03-12 22:05:55 INFO  SorterBenchmark - run: sort 16,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 22:05:55 INFO  Benchmark_Timer - Begin run: Instrumenting helper for MergeSort: with 16,000 elements with 1 runs
Compares : 6.3597271E7
Hits : 2.54737764E8
Swaps : 6.3487131E7
Copies : 378624.0
2023-03-12 22:05:56 INFO  TimeLogger - Raw time per run (mSec):  341.61
2023-03-12 22:05:56 INFO  TimeLogger - Normalized time per run (n log n):  284.14
```

```
2023-03-12 22:06:00 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 22:06:00 INFO  SortBenchmark - Testing with 1 runs of sorting 32,000 words and instrumented
2023-03-12 22:06:00 INFO  SorterBenchmark - run: sort 32,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 22:06:00 INFO  Benchmark_Timer - Begin run: Instrumenting helper for MergeSort: with 32,000 elements with 1 runs
Compares : 2.57026794E8
Hits : 1.028868532E9
Swaps : 2.56790512E8
Copies : 821248.0
2023-03-12 22:06:05 INFO  TimeLogger - Raw time per run (mSec):  1526.33
2023-03-12 22:06:05 INFO  TimeLogger - Normalized time per run (n log n):  587.85
```

Quick Sort with Instrumenting

```
2023-03-12 20:52:39 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 20:52:39 INFO  SortBenchmark - Testing with 1 runs of sorting 10,000 words and instrumented
2023-03-12 20:52:39 INFO  SorterBenchmark - run: sort 10,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 20:52:39 INFO  Benchmark_Timer - Begin run: Instrumenting helper for QuickSort dual pivot with 10,000 elements with 1 runs
Compares : 167466.0
Hits : 447958.0
Swaps : 68722.0
Copies : 0.0
2023-03-12 20:52:40 INFO  TimeLogger - Raw time per run (mSec):  362.64
2023-03-12 20:52:40 INFO  TimeLogger - Normalized time per run (n log n):  510.22
```

```
2023-03-12 20:52:42 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 20:52:42 INFO  SortBenchmark - Testing with 1 runs of sorting 16,000 words and instrumented
2023-03-12 20:52:42 INFO  SorterBenchmark - run: sort 16,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 20:52:42 INFO  Benchmark_Timer - Begin run: Instrumenting helper for QuickSort dual pivot with 16,000 elements with 1 runs
Compares : 271863.0
Hits : 741058.0
Swaps : 114953.0
Copies : 0.0
2023-03-12 20:52:45 INFO  TimeLogger - Raw time per run (mSec):  1179.18
2023-03-12 20:52:45 INFO  TimeLogger - Normalized time per run (n log n):  980.80
```

```
2023-03-12 20:52:55 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 20:52:55 INFO  SortBenchmark - Testing with 1 runs of sorting 32,000 words and instrumented
2023-03-12 20:52:55 INFO  SorterBenchmark - run: sort 32,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 20:52:55 INFO  Benchmark_Timer - Begin run: Instrumenting helper for QuickSort dual pivot with 32,000 elements with 1 runs
Compares : 572414.0
Hits : 1495229.0
Swaps : 225404.0
Copies : 0.0
2023-03-12 20:53:07 INFO  TimeLogger - Raw time per run (mSec):  2541.05
2023-03-12 20:53:07 INFO  TimeLogger - Normalized time per run (n log n):  978.65
```

Heap Sort with Instrumenting

```
2023-03-12 21:30:20 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 21:30:20 INFO  SortBenchmark - Testing pure sorts with 1 runs of sorting 10,000 words
2023-03-12 21:30:20 INFO  SorterBenchmark - run: sort 10,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 21:30:20 INFO  Benchmark_Timer - Begin run: Instrumenting helper for Heapsort with 10,000 elements with 1 runs
Compares : 235389.0
Hits : 967346.0
Swaps : 124142.0
Copies : 0.0
2023-03-12 21:30:22 INFO  TimeLogger - Raw time per run (mSec):  715.24
2023-03-12 21:30:22 INFO  TimeLogger - Normalized time per run (n log n):  1006.31
2023-03-12 21:30:22 INFO  SortBenchmarkHelper - Testing with words: 22,865 from eng-uk_web_2002_10K-sentences.txt
2023-03-12 21:30:22 INFO  SortBenchmark - Testing pure sorts with 1 runs of sorting 16,000 words
2023-03-12 21:30:22 INFO  SorterBenchmark - run: sort 16,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 21:30:22 INFO  Benchmark_Timer - Begin run: Instrumenting helper for Heapsort with 16,000 elements with 1 runs
Compares : 397699.0
Hits : 1632450.0
Swaps : 209263.0
Copies : 0.0
2023-03-12 21:30:28 INFO  TimeLogger - Raw time per run (mSec):  1800.34
2023-03-12 21:30:28 INFO  TimeLogger - Normalized time per run (n log n):  1497.45
```

```
2023-03-12 21:30:28 INFO  SortBenchmark - Testing pure sorts with 1 runs of sorting 32,000 words
2023-03-12 21:30:28 INFO  SorterBenchmark - run: sort 32,000 elements using SorterBenchmark on class java.lang.String from 22,865 total elements and 1 runs using sorter:
2023-03-12 21:30:28 INFO  Benchmark_Timer - Begin run: Instrumenting helper for Heapsort with 32,000 elements with 1 runs
Compares : 859415.0
Hits : 3521262.0
Swaps : 450608.0
Copies : 0.0
2023-03-12 21:30:49 INFO  TimeLogger - Raw time per run (mSec):  7168.61
2023-03-12 21:30:49 INFO  TimeLogger - Normalized time per run (n log n):  2760.89
```