Program structures and Algorithm’s

Fall 23

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**TASK**:

To determine the best predictor of total execution time by running benchmarks for merge sort, quick sort (dual-pivot), and heap sort. Following parameters are checked for determining the best predictor

1. swaps  
   b. compares c. copies  
   d. hits

**RELATIONSHIP CONCLUSION**:

The frequency of array access, denoted as "hits," emerges as the foremost indicator of the overall execution time across comparison-based sorting algorithms like quick sort, merge sort, and heap sort. Array access significantly influences sorting algorithm performance due to its potential time and resource costs. Moreover, the manner in which array elements are accessed can impact sorting algorithm efficiency. For instance, algorithms requiring random element access may experience frequent cache misses, necessitating data retrieval from main memory, which is slower than accessing cached data.

In merge sort, additional memory is necessitated for copying values, with no swapping involved. During value copying from auxiliary memory, comparisons facilitate pointer movement in sub-arrays. Consequently, the descending order of impact on total execution time is hits, copies, comparisons, and swaps (which are nearly negligible).

Conversely, heap sort and quicksort do not require additional memory, eliminating time spent on copy operations. Instead, they establish proper partitions within the array by continuously comparing and swapping elements. Consequently, the descending order of impact on total execution time is hits, comparisons, and swaps, with copying playing no role.

Furthermore, when plotting normalized metrics, the hits graph closely mirrors the time graph across all sorting algorithms, suggesting it serves as the most reliable predictor of total execution time.

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**EVIDENCE TO SUPPORT THAT CONCLUSION**

Instrumentation:

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**Quick Dual Pivot Sort**

| **N** | **Compares (mean)** | **Hits (mean)** | **Copies (mean)** | **Swaps (mean)** | **Time (normalized)** |
| --- | --- | --- | --- | --- | --- |
| 10000 | 156,086 | 423,442 | 0 | 66,395 | 1.53 |
| 20000 | 340,671 | 912,283 | 0 | 141,627 | 2.92 |
| 40000 | 739,229 | 1,946,617 | 0 | 297,881 | 4.60 |
| 80000 | 1,588,867 | 4,236,166 | 0 | 656,359 | 4.69 |

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**Heap Sort**

| **N** | **Compares (mean)** | **Hits (mean)** | **Copies (mean)** | **Swaps (mean)** | **Time (normalized)** |
| --- | --- | --- | --- | --- | --- |
| 10000 | 235,370 | 967,555 | 0 | 124,204 | 3.85 |
| 20000 | 510,750 | 2,095,111 | 0 | 268,403 | 4.01 |
| 40000 | 1,101,504 | 4,510,197 | 0 | 576,797 | 4.67 |
| 80000 | 2,202,016 | 9,660,173 | 0 | 1,154,766 | 10.64 |

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**Merge Sort**

| **N** | **Compares (mean)** | **Hits (mean)** | **Copies (mean)** | **Swaps (mean)** | **Time (normalized)** |
| --- | --- | --- | --- | --- | --- |
| 10000 | 121,501 | 489,776 | 220,000 | 9,758 | 3.77 |
| 20000 | 263,010 | 1,059,567 | 480,000 | 19,518 | 3.35 |
| 40000 | 566,002 | 2,279,038 | 1,040,000 | 39,010 | 3.62 |
| 80000 | 1,212,033 | 4,878,269 | 2,240,000 | 78,082 | 3.62 |

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Non Instrumentation:  
  
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Merge Sort  
  
Merge Sort Table:

N Compares Swaps Hits Time (ms)

10000 235369 124200 967539 2.58

20000 510746 268401 2095097 5.75

40000 1101501 576802 4510210 12.81

80000 1212028 78082 4878279 29.49

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Description automatically generated

**Heap Sort**

| **N** | **Compares** | **Hits** | **Swaps** | **Time (ms)** |
| --- | --- | --- | --- | --- |
| **10,000** | **235,369** | **967,539** | **124,200** | **2.58** |
| **20,000** | **510,746** | **2,095,097** | **268,401** | **5.75** |
| **40,000** | **1,101,501** | **4,510,210** | **576,802** | **12.81** |
| **80,000** | **1,212,028** | **4,878,279** | **78,082** | **29.49** |

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**QuickSort dual pivot**

| **N** | **Compares** | **Hits** | **Swaps** | **Time (ms)** |
| --- | --- | --- | --- | --- |
| **10,000** | **155,615** | **423,690** | **66,575** | **2.02** |
| **20,000** | **341,262** | **914,287** | **141,985** | **4.29** |
| **40,000** | **741,161** | **1,948,759** | **297,931** | **9.34** |
| **80,000** | **1,581,480** | **4,211,701** | **652,095** | **19.55** |

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Test case SS:  
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