PSA Assignment 6
002791446

Code:
https://github.com/rohitpanicker06/INFO6205/tree/Assignment_SIX_002791446

Conclusion:
We have executed two tests with instrumentation on and off, and by comparing both of them we can conclude that the hits, copies, swaps and compares can be the predictors. Also since the graph of **hits** is more linear we can consider hits to be the more accurate predictor.

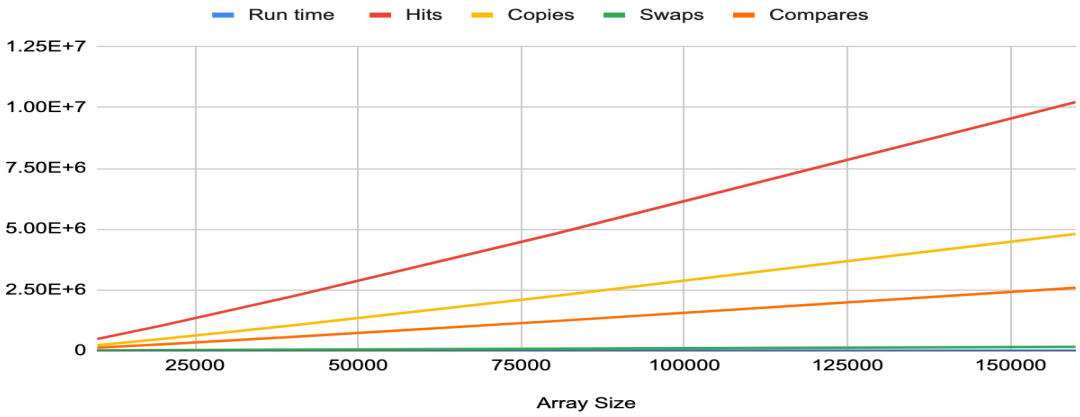
Graphical Representation:

	Merge Sort				
Array Size	Run time	Hits	Copies	Swaps	Compares
10000	2.1	478,943	220,000	9,736	121,524
20000	2.2	1,037,834	480,000	19,458	262,973
40000	5.1	2,236,530	1,040,000	39,133	566,097
80000	10.9	4,792,219	2,240,000	78,055	1,212,135
160000	23.7	10,224,385	4,800,000	156,096	2,584,017

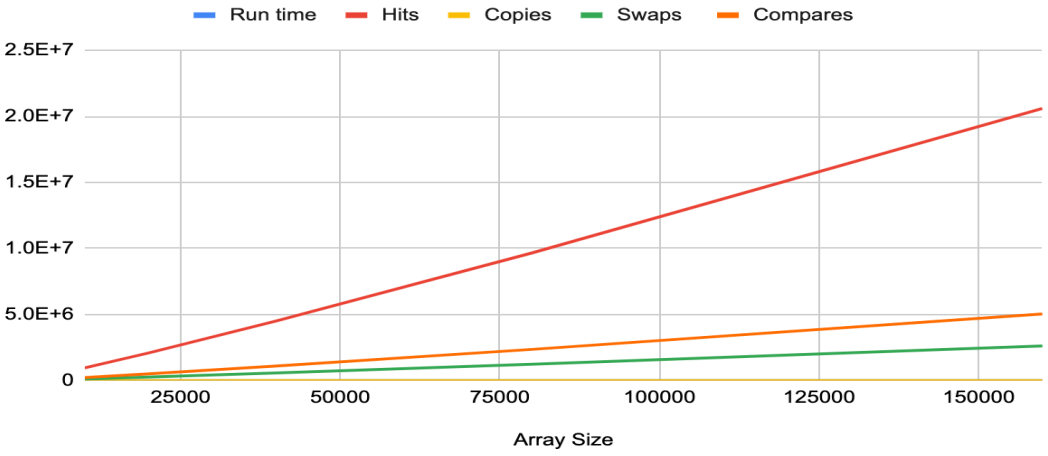
	Heap Sort				
Array Size	Run time	Hits	Copies	Swaps	Compares
10000	1.7	967,466	0	124,187	235,360
20000	3.1	2,095,557	0	268,476	510,826
40000	6.1	4,510,571	0	576,879	1,101,528
80000	12.9	9,660,134	0	1,233,536	2,362,994
160000	27.9	20,600,636	0	2,627,173	5,045,973

	Dual Pivot Quick Sort				
Array Size	Run time	Hits	Copies	Swaps	Compares
10000	2	413,682	0	65,788	154,895
20000	9.3	884,560	0	138,008	341,237
40000	4.5	1,938,229	0	306,929	727,857
80000	9.4	4,145,994	0	652,089	1,572,553
160000	23.3	9,019,253	0	1,411,525	3,442,560

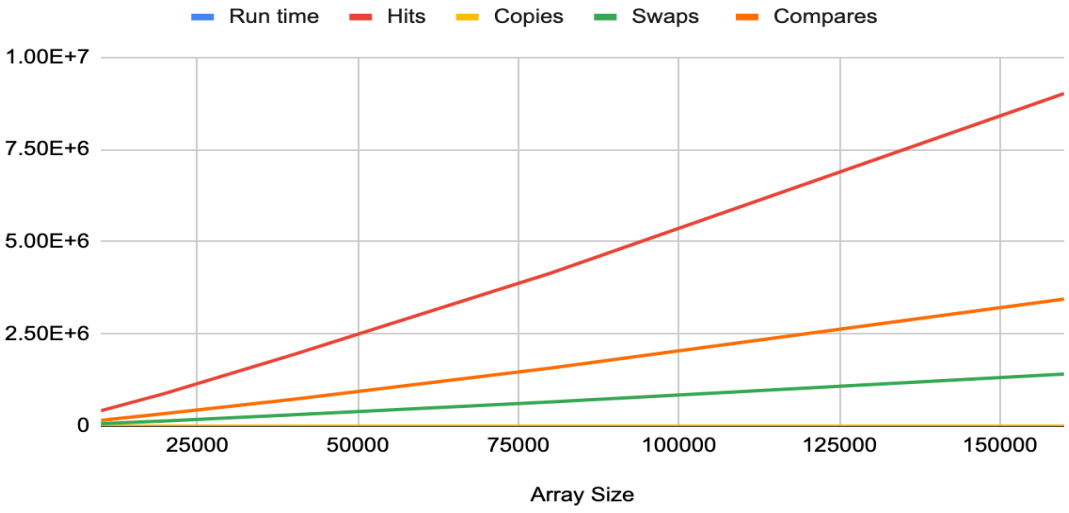
Merge Sort



Heap Sort



Dual Pivot Quick Sort



TEST OUTPUT:

```
/opt/homebrew/Cellar/openjdk/19/libexec/openjdk.jdk/Contents/Home/bin/java
-javaagent:/Applications/IntelliJ IDEA CE.app/Contents/lib/idea_rt.jar=49366:/Applications/IntelliJ
IDEA CE.app/Contents/bin -Dfile.encoding=UTF-8 -Dsun.stdout.encoding=UTF-8
-Dsun.stderr.encoding=UTF-8 -classpath /Users/rohitpanicker/Desktop/NEU/SEM
2/PSA/INFO6205/target/classes:/Users/rohitpanicker/.m2/repository/com/phasmidsoftware/args_2
.13/1.0.3/args_2.13-1.0.3.jar:/Users/rohitpanicker/.m2/repository/org/scala-lang/scala-library/2.13.
7/scala-library-2.13.7.jar:/Users/rohitpanicker/.m2/repository/org/scala-lang/modules/scala-parser-
combinators_2.13/1.1.2/scala-parser-combinators_2.13-1.1.2.jar:/Users/rohitpanicker/.m2/reposit
ory/org/apache/logging/log4j/log4j-api/2.19.0/log4j-api-2.19.0.jar:/Users/rohitpanicker/.m2/reposito
ry/log4j/log4j/1.2.17/log4j-1.2.17.jar:/Users/rohitpanicker/.m2/repository/com/google/guava/guava/
31.1-jre/guava-31.1-jre.jar:/Users/rohitpanicker/.m2/repository/com/google/guava/failureaccess/1.
0.1/failureaccess-1.0.1.jar:/Users/rohitpanicker/.m2/repository/com/google/guava/listenablefuture/
9999.0-empty-to-avoid-conflict-with-guava/listenablefuture-9999.0-empty-to-avoid-conflict-with-gu
ava.jar:/Users/rohitpanicker/.m2/repository/com/google/code/findbugs/jsr305/3.0.2/jsr305-3.0.2.jar
:/Users/rohitpanicker/.m2/repository/org/checkerframework/checker-qual/3.12.0/checker-qual-3.12
.0.jar:/Users/rohitpanicker/.m2/repository/com/google/errorprone/error_prone_annotations/2.11.0/
error_prone_annotations-2.11.0.jar:/Users/rohitpanicker/.m2/repository/com/google/j2objc/j2objc-a
nnotations/1.3/j2objc-annotations-1.3.jar:/Users/rohitpanicker/.m2/repository/org/ini4j/ini4j/0.5.4/ini
4j-0.5.4.jar edu.neu.coe.info6205.util.SortBenchmark
2023-03-12 23:34:30 INFO  SortBenchmark - SortBenchmark.main: 1.0.0 (sortbenchmark) with
min: 10000 max: 256000 strategy: doubling
2023-03-12 23:34:30 INFO  SorterBenchmark - run: sort 10,000 elements using SorterBenchmark
on class java.lang.Integer from 10,000 total elements and 10 runs using sorter: MergeSortBasic
2023-03-12 23:34:30 INFO  Benchmark_Timer - Begin run: Instrumenting helper for
MergeSortBasic with 10,000 elements with 10 runs
2023-03-12 23:34:30 INFO  TimeLogger - Raw time per run (mSec):  2.30
2023-03-12 23:34:30 INFO  TimeLogger - Normalized time per run (n log n):  3.24
2023-03-12 23:34:30 INFO  SortBenchmark - MergeSortBasic: StatPack {hits: mean=479,034;
stdDev=393, normalized=5.201; copies: 220,000, normalized=2.389; inversions: <unset>; swaps:
mean=9,758; stdDev=98, normalized=0.106; fixes: mean=25,041,334; stdDev=215,662,
normalized=271.883; compares: mean=121,471; stdDev=97, normalized=1.319}
2023-03-12 23:34:30 INFO  SorterBenchmark - run: sort 10,000 elements using SorterBenchmark
on class java.lang.Integer from 10,000 total elements and 10 runs using sorter: HeapSort
2023-03-12 23:34:30 INFO  Benchmark_Timer - Begin run: Instrumenting helper for HeapSort
with 10,000 elements with 10 runs
2023-03-12 23:34:32 INFO  TimeLogger - Raw time per run (mSec):  181.60
2023-03-12 23:34:32 INFO  TimeLogger - Normalized time per run (n log n):  255.51
2023-03-12 23:34:32 INFO  SortBenchmark - HeapSort: StatPack {hits: mean=967,466;
stdDev=601, normalized=10.504; copies: 0, normalized=0.000; inversions: <unset>; swaps:
mean=124,187; stdDev=101, normalized=1.348; fixes: mean=75,427,451; stdDev=270,868,
normalized=818.943; compares: mean=235,360; stdDev=103, normalized=2.555}
```

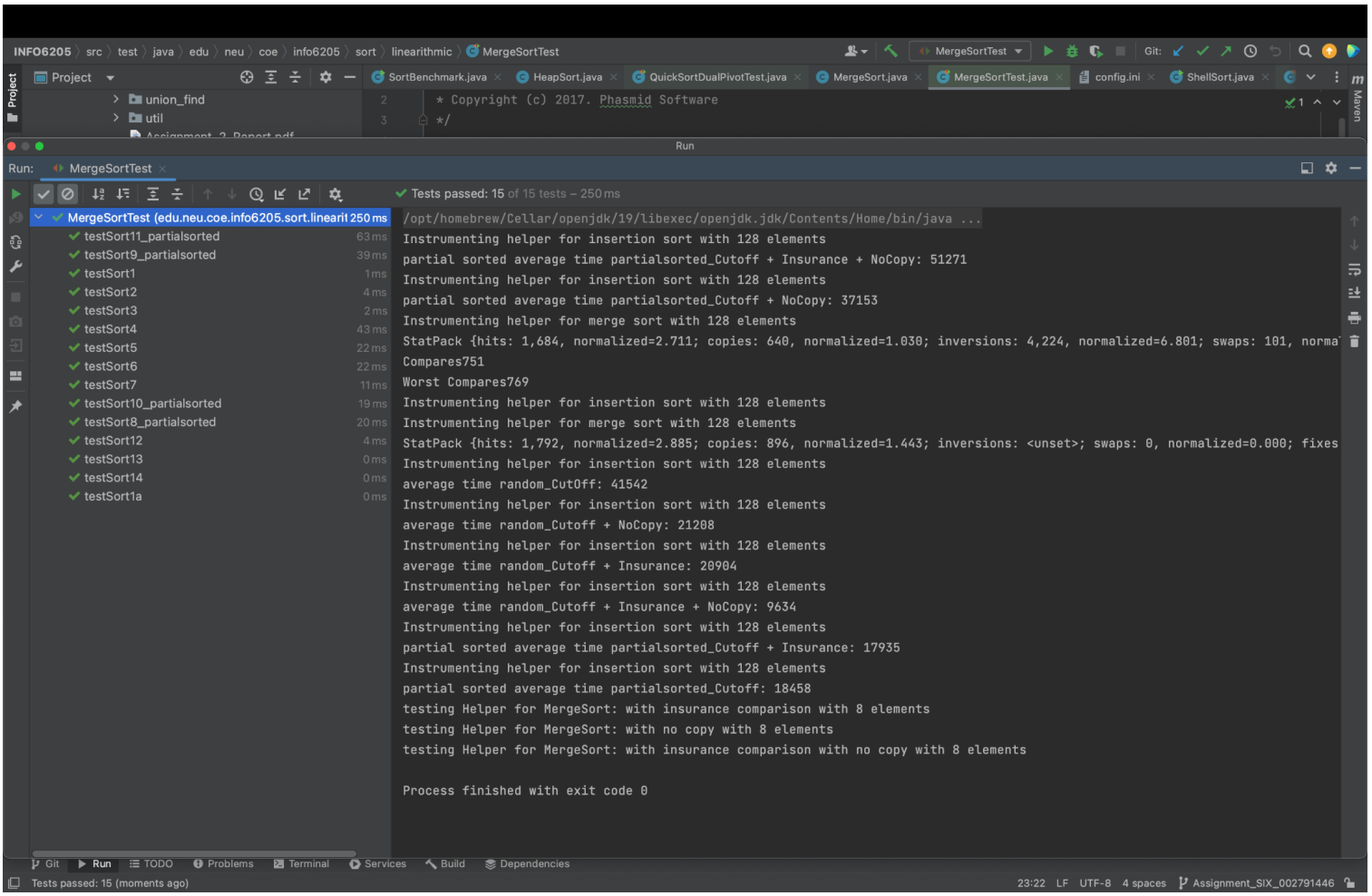
2023-03-12 23:34:32 INFO SorterBenchmark - run: sort 10,000 elements using SorterBenchmark on class java.lang.Integer from 10,000 total elements and 10 runs using sorter: QuickSort_DualPivot
2023-03-12 23:34:32 INFO Benchmark_Timer - Begin run: Instrumenting helper for QuickSort_DualPivot with 10,000 elements with 10 runs
2023-03-12 23:34:34 INFO TimeLogger - Raw time per run (mSec): 160.80
2023-03-12 23:34:34 INFO TimeLogger - Normalized time per run (n log n): 226.24
2023-03-12 23:34:34 INFO SortBenchmark - QuickSort_DualPivot: StatPack {hits: mean=413,682; stdDev=20,177, normalized=4.491; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=65,788; stdDev=3,545, normalized=0.714; fixes: mean=29,140,003; stdDev=4,022,480, normalized=316.384; compares: mean=154,895; stdDev=7,492, normalized=1.682}
2023-03-12 23:34:34 INFO SorterBenchmark - run: sort 20,000 elements using SorterBenchmark on class java.lang.Integer from 20,000 total elements and 10 runs using sorter: MergeSortBasic
2023-03-12 23:34:34 INFO Benchmark_Timer - Begin run: Instrumenting helper for MergeSortBasic with 20,000 elements with 10 runs
2023-03-12 23:34:34 INFO TimeLogger - Raw time per run (mSec): 2.40
2023-03-12 23:34:34 INFO TimeLogger - Normalized time per run (n log n): 1.56
2023-03-12 23:34:34 INFO SortBenchmark - MergeSortBasic: StatPack {hits: mean=1,038,064; stdDev=619, normalized=5.241; copies: 480,000, normalized=2.423; inversions: <unset>; swaps: mean=19,516; stdDev=155, normalized=0.099; fixes: mean=99,847,938; stdDev=267,111, normalized=504.105; compares: mean=263,041; stdDev=112, normalized=1.328}
2023-03-12 23:34:34 INFO SorterBenchmark - run: sort 20,000 elements using SorterBenchmark on class java.lang.Integer from 20,000 total elements and 10 runs using sorter: HeapSort
2023-03-12 23:34:34 INFO Benchmark_Timer - Begin run: Instrumenting helper for HeapSort with 20,000 elements with 10 runs
2023-03-12 23:34:43 INFO TimeLogger - Raw time per run (mSec): 738.90
2023-03-12 23:34:43 INFO TimeLogger - Normalized time per run (n log n): 479.35
2023-03-12 23:34:43 INFO SortBenchmark - HeapSort: StatPack {hits: mean=2,095,557; stdDev=599, normalized=10.580; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=268,476; stdDev=96, normalized=1.355; fixes: mean=302,756,322; stdDev=446,633, normalized=1528.534; compares: mean=510,826; stdDev=121, normalized=2.579}
2023-03-12 23:34:43 INFO SorterBenchmark - run: sort 20,000 elements using SorterBenchmark on class java.lang.Integer from 20,000 total elements and 10 runs using sorter: QuickSort_DualPivot
2023-03-12 23:34:43 INFO Benchmark_Timer - Begin run: Instrumenting helper for QuickSort_DualPivot with 20,000 elements with 10 runs
2023-03-12 23:34:49 INFO TimeLogger - Raw time per run (mSec): 490.10
2023-03-12 23:34:49 INFO TimeLogger - Normalized time per run (n log n): 317.95
2023-03-12 23:34:49 INFO SortBenchmark - QuickSort_DualPivot: StatPack {hits: mean=884,560; stdDev=44,783, normalized=4.466; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=138,008; stdDev=7,561, normalized=0.697; fixes: mean=113,064,623;

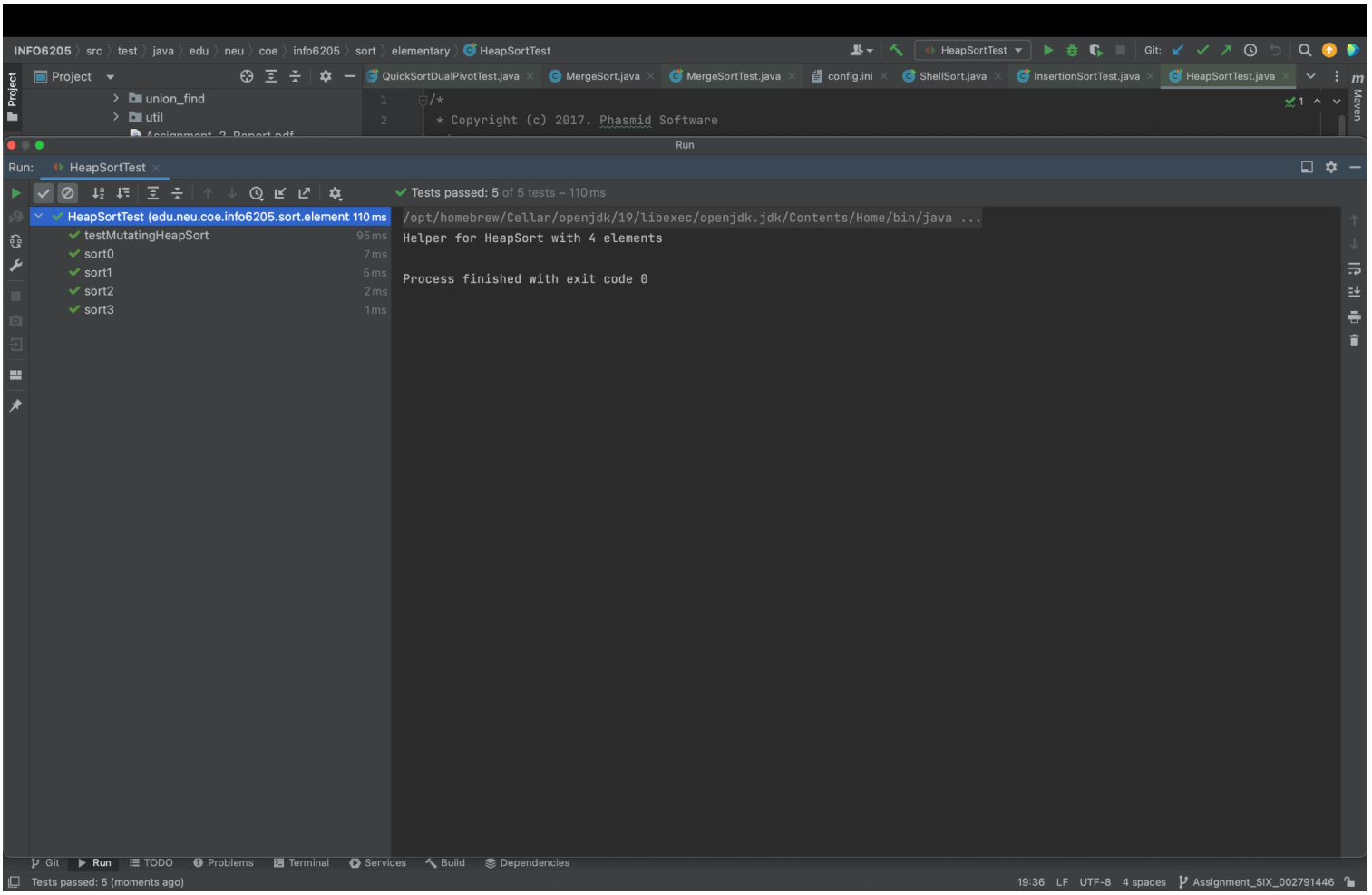
stdDev=18,720,895, normalized=570.832; compares: mean=341,237; stdDev=20,237, normalized=1.723}
2023-03-12 23:34:49 INFO SorterBenchmark - run: sort 40,000 elements using SorterBenchmark on class java.lang.Integer from 40,000 total elements and 10 runs using sorter: MergeSortBasic
2023-03-12 23:34:49 INFO Benchmark_Timer - Begin run: Instrumenting helper for MergeSortBasic with 40,000 elements with 10 runs
2023-03-12 23:34:49 INFO TimeLogger - Raw time per run (mSec): 5.10
2023-03-12 23:34:49 INFO TimeLogger - Normalized time per run (n log n): 1.53
2023-03-12 23:34:49 INFO SortBenchmark - MergeSortBasic: StatPack {hits: mean=2,235,978; stdDev=722, normalized=5.275; copies: 1,040,000, normalized=2.454; inversions: <unset>; swaps: mean=38,995; stdDev=181, normalized=0.092; fixes: mean=399,315,560; stdDev=1,372,031, normalized=942.081; compares: mean=565,986; stdDev=122, normalized=1.335}
2023-03-12 23:34:49 INFO SorterBenchmark - run: sort 40,000 elements using SorterBenchmark on class java.lang.Integer from 40,000 total elements and 10 runs using sorter: HeapSort
2023-03-12 23:34:49 INFO Benchmark_Timer - Begin run: Instrumenting helper for HeapSort with 40,000 elements with 10 runs
2023-03-12 23:35:27 INFO TimeLogger - Raw time per run (mSec): 3167.40
2023-03-12 23:35:27 INFO TimeLogger - Normalized time per run (n log n): 953.22
2023-03-12 23:35:27 INFO SortBenchmark - HeapSort: StatPack {hits: mean=4,510,571; stdDev=543, normalized=10.642; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=576,879; stdDev=96, normalized=1.361; fixes: mean=1,211,286,241; stdDev=1,042,700, normalized=2857.714; compares: mean=1,101,528; stdDev=103, normalized=2.599}
2023-03-12 23:35:27 INFO SorterBenchmark - run: sort 40,000 elements using SorterBenchmark on class java.lang.Integer from 40,000 total elements and 10 runs using sorter: QuickSort_DualPivot
2023-03-12 23:35:27 INFO Benchmark_Timer - Begin run: Instrumenting helper for QuickSort_DualPivot with 40,000 elements with 10 runs
2023-03-12 23:35:57 INFO TimeLogger - Raw time per run (mSec): 2549.90
2023-03-12 23:35:57 INFO TimeLogger - Normalized time per run (n log n): 767.38
2023-03-12 23:35:57 INFO SortBenchmark - QuickSort_DualPivot: StatPack {hits: mean=1,938,229; stdDev=83,179, normalized=4.573; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=306,929; stdDev=16,012, normalized=0.724; fixes: mean=462,538,961; stdDev=63,269,190, normalized=1091.240; compares: mean=727,857; stdDev=27,142, normalized=1.717}
2023-03-12 23:35:57 INFO SorterBenchmark - run: sort 80,000 elements using SorterBenchmark on class java.lang.Integer from 80,000 total elements and 10 runs using sorter: MergeSortBasic
2023-03-12 23:35:57 INFO Benchmark_Timer - Begin run: Instrumenting helper for MergeSortBasic with 80,000 elements with 10 runs
2023-03-12 23:35:57 INFO TimeLogger - Raw time per run (mSec): 11.20
2023-03-12 23:35:57 INFO TimeLogger - Normalized time per run (n log n): 1.57
2023-03-12 23:35:57 INFO SortBenchmark - MergeSortBasic: StatPack {hits: mean=4,792,538; stdDev=1,002, normalized=5.306; copies: 2,240,000, normalized=2.480; inversions: <unset>;

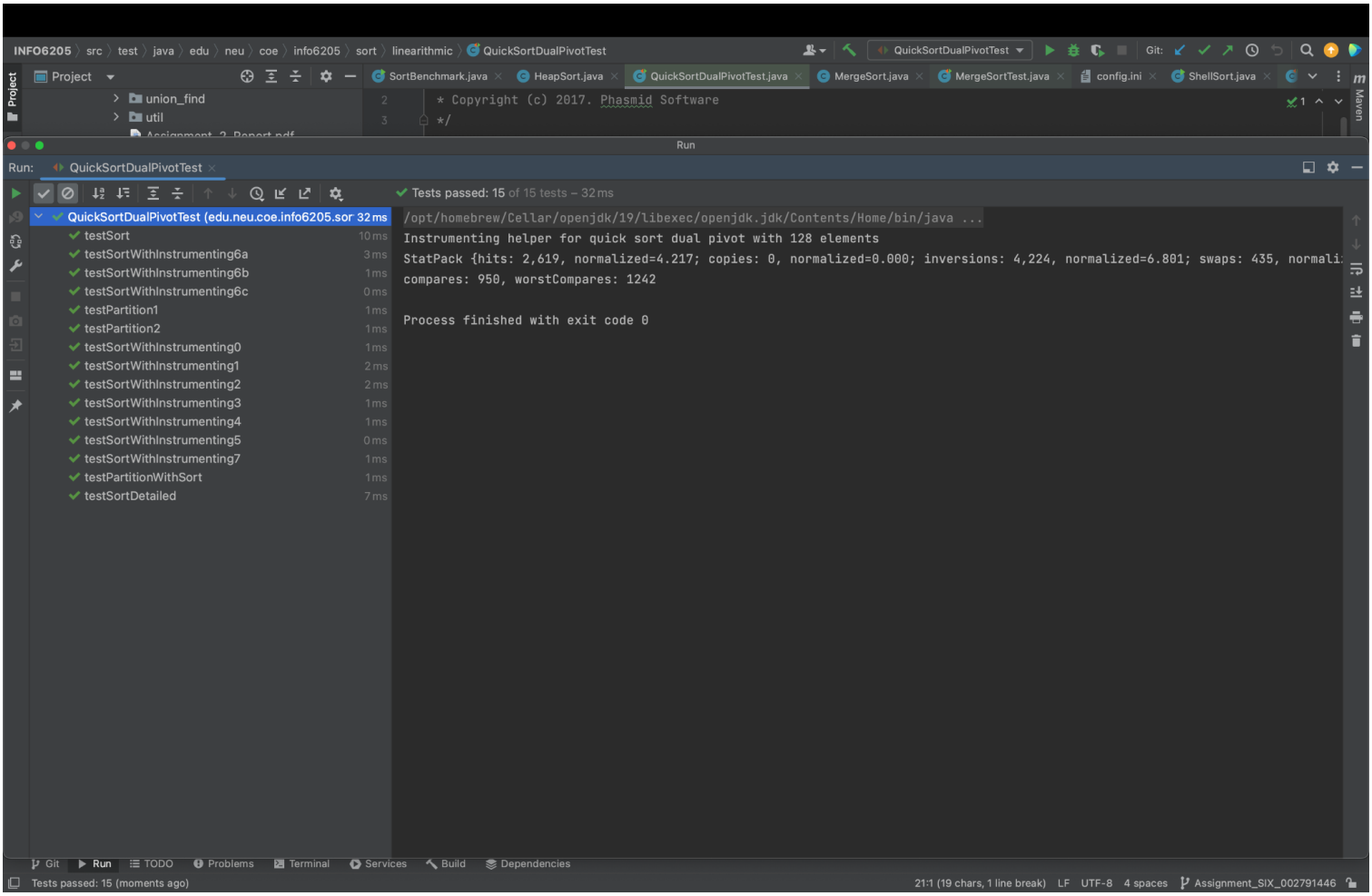
swaps: mean=78,135; stdDev=250, normalized=0.087; fixes: mean=1,601,533,912; stdDev=4,892,570, normalized=1773.212; compares: mean=1,212,009; stdDev=213, normalized=1.342}
2023-03-12 23:35:57 INFO SorterBenchmark - run: sort 80,000 elements using SorterBenchmark on class java.lang.Integer from 80,000 total elements and 10 runs using sorter: HeapSort
2023-03-12 23:35:57 INFO Benchmark_Timer - Begin run: Instrumenting helper for HeapSort with 80,000 elements with 10 runs
2023-03-12 23:38:32 INFO TimeLogger - Raw time per run (mSec): 12758.30
2023-03-12 23:38:32 INFO TimeLogger - Normalized time per run (n log n): 1790.47
2023-03-12 23:38:32 INFO SortBenchmark - HeapSort: StatPack {hits: mean=9,660,134; stdDev=797, normalized=10.696; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=1,233,536; stdDev=122, normalized=1.366; fixes: mean=546,214,362; stdDev=4,205,507, normalized=604.766; compares: mean=2,362,994; stdDev=186, normalized=2.616}
2023-03-12 23:38:32 INFO SorterBenchmark - run: sort 80,000 elements using SorterBenchmark on class java.lang.Integer from 80,000 total elements and 10 runs using sorter: QuickSort_DualPivot
2023-03-12 23:38:32 INFO Benchmark_Timer - Begin run: Instrumenting helper for QuickSort_DualPivot with 80,000 elements with 10 runs
2023-03-12 23:40:07 INFO TimeLogger - Raw time per run (mSec): 8423.70
2023-03-12 23:40:07 INFO TimeLogger - Normalized time per run (n log n): 1182.16
2023-03-12 23:40:07 INFO SortBenchmark - QuickSort_DualPivot: StatPack {hits: mean=4,145,994; stdDev=140,997, normalized=4.590; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=652,089; stdDev=26,430, normalized=0.722; fixes: mean=1,779,514,334; stdDev=101,948,113, normalized=1970.271; compares: mean=1,572,553; stdDev=43,050, normalized=1.741}
2023-03-12 23:40:07 INFO SorterBenchmark - run: sort 160,000 elements using SorterBenchmark on class java.lang.Integer from 160,000 total elements and 10 runs using sorter: MergeSortBasic
2023-03-12 23:40:07 INFO Benchmark_Timer - Begin run: Instrumenting helper for MergeSortBasic with 160,000 elements with 10 runs
2023-03-12 23:40:08 INFO TimeLogger - Raw time per run (mSec): 24.90
2023-03-12 23:40:08 INFO TimeLogger - Normalized time per run (n log n): 1.64
2023-03-12 23:40:08 INFO SortBenchmark - MergeSortBasic: StatPack {hits: mean=10,224,385; stdDev=1,160, normalized=5.333; copies: 4,800,000, normalized=2.504; inversions: <unset>; swaps: mean=156,096; stdDev=290, normalized=0.081; fixes: mean=2,104,605,835; stdDev=5,280,291, normalized=1097.710; compares: mean=2,584,017; stdDev=326, normalized=1.348}
2023-03-12 23:40:08 INFO SorterBenchmark - run: sort 160,000 elements using SorterBenchmark on class java.lang.Integer from 160,000 total elements and 10 runs using sorter: HeapSort
2023-03-12 23:40:08 INFO Benchmark_Timer - Begin run: Instrumenting helper for HeapSort with 160,000 elements with 10 runs
2023-03-12 23:50:55 INFO TimeLogger - Raw time per run (mSec): 53696.60

2023-03-12 23:50:55 INFO TimeLogger - Normalized time per run (n log n): 3530.05
2023-03-12 23:50:55 INFO SortBenchmark - HeapSort: StatPack {hits: mean=20,600,636; stdDev=1,325, normalized=10.745; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=2,627,173; stdDev=214, normalized=1.370; fixes: mean=-2,099,903,435; stdDev=10,658,115, normalized=-1095.258; compares: mean=5,045,973; stdDev=281, normalized=2.632}
2023-03-12 23:50:55 INFO SorterBenchmark - run: sort 160,000 elements using SorterBenchmark on class java.lang.Integer from 160,000 total elements and 10 runs using sorter: QuickSort_DualPivot
2023-03-12 23:50:55 INFO Benchmark_Timer - Begin run: Instrumenting helper for QuickSort_DualPivot with 160,000 elements with 10 runs
2023-03-12 23:59:30 INFO TimeLogger - Raw time per run (mSec): 44697.20
2023-03-12 23:59:30 INFO TimeLogger - Normalized time per run (n log n): 2938.43
2023-03-12 23:59:30 INFO SortBenchmark - QuickSort_DualPivot: StatPack {hits: mean=9,019,253; stdDev=319,935, normalized=4.704; copies: 0, normalized=0.000; inversions: <unset>; swaps: mean=1,411,525; stdDev=69,092, normalized=0.736; fixes: mean=-1,196,680,823; stdDev=854,876,322, normalized=-624.159; compares: mean=3,442,560; stdDev=109,698, normalized=1.796}

Process finished with exit code 0




INFO6205 src test java edu neu coe info6205 sort elementary HeapSortTest
HeapSortTest
Git:
Project
union_find
util
QuickSortDualPivotTest.java
MergeSort.java
MergeSortTest.java
config.ini
ShellSort.java
InsertionSortTest.java
HeapSortTest.java
1 /*
2 * Copyright (c) 2017. Phasmid Software
Run
Run: HeapSortTest
Tests passed: 5 of 5 tests – 110 ms
HeapSortTest (edu.neu.coe.info6205.sort.element 110 ms
testMutatingHeapSort 95 ms
sort0 7 ms
sort1 5 ms
sort2 2 ms
sort3 1 ms
/opt/homebrew/Cellar/openjdk/19/libexec/openjdk.jdk/Contents/Home/bin/java ...
Helper for HeapSort with 4 elements
Process finished with exit code 0
Git Run TODO Problems Terminal Services Build Dependencies
Tests passed: 5 (moments ago)
19:36 LF UTF-8 4 spaces Assignment_SIX_002791446


INFO6205 src test java edu neu coe info6205 sort linearithmic QuickSortDualPivotTest
QuickSortDualPivotTest
Git:
Project
union_find
util
SortBenchmark.java
HeapSort.java
QuickSortDualPivotTest.java
MergeSort.java
MergeSortTest.java
config.ini
ShellSort.java
* Copyright (c) 2017. Phasmid Software
*/
Run
Run: QuickSortDualPivotTest
Tests passed: 15 of 15 tests – 32 ms
QuickSortDualPivotTest (edu.neu.coe.info6205.sor 32 ms
testSort 10 ms
testSortWithInstrumenting6a 3 ms
testSortWithInstrumenting6b 1 ms
testSortWithInstrumenting6c 0 ms
testPartition1 1 ms
testPartition2 1 ms
testSortWithInstrumenting0 1 ms
testSortWithInstrumenting1 2 ms
testSortWithInstrumenting2 2 ms
testSortWithInstrumenting3 1 ms
testSortWithInstrumenting4 1 ms
testSortWithInstrumenting5 0 ms
testSortWithInstrumenting7 1 ms
testPartitionWithSort 1 ms
testSortDetailed 7 ms
/opt/homebrew/Cellar/openjdk/19/libexec/openjdk.jdk/Contents/Home/bin/java ...
Instrumenting helper for quick sort dual pivot with 128 elements
StatPack {hits: 2,619, normalized=4.217; copies: 0, normalized=0.000; inversions: 4,224, normalized=6.801; swaps: 435, normali
compares: 950, worstCompares: 1242
Process finished with exit code 0
Git Run TODO Problems Terminal Services Build Dependencies
Tests passed: 15 (moments ago)
21:1 (19 chars, 1 line break) LF UTF-8 4 spaces Assignment_SIX_002791446