

# Program Structures & Algorithms

## Fall 2021

### Assignment No. 2

- **Tasks:**

- Implemented the code to Benchmark any algorithm(code).
- Insertion sort implementation using the helper methods.
- Wrote and executed the main program to run the benchmarks for Insertion sort with various types like Ordered elements, Reverse ordered elements, Partially ordered elements, Randomly ordered elements.

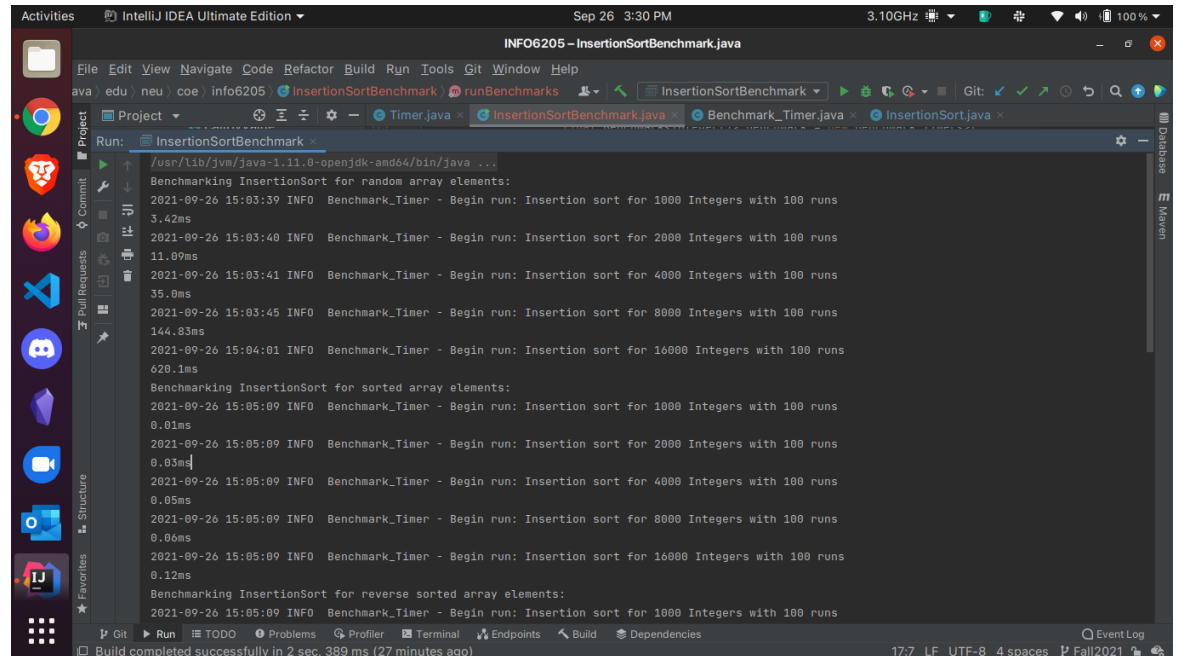
- **Relationship Conclusion:**

- The relationship between the **number of elements in the array** and **the running time of the Insertion sort algorithm** is  **$O(N^2)$  - Worst Case** in the worst case i.e. for the reversed sorted array as well as a randomly ordered array and for **an ordered array** it is  **$O(N)$  - Best case**.
- This means that for the reverse ordered array and a randomly ordered array *if we double the number of elements in the array, the running time increases four times (squared)*.
- And for the sorted array, if we double the number of elements in the array, the running time increases in **N** times.
- For the partially sorted array, this relationship is somewhere between the **Worst-case -  $O(N^2)$**  and the **Best-case -  $O(N)$**  but almost similar to the worst case which is  **$O(N^2)$** .

(To be continued...)

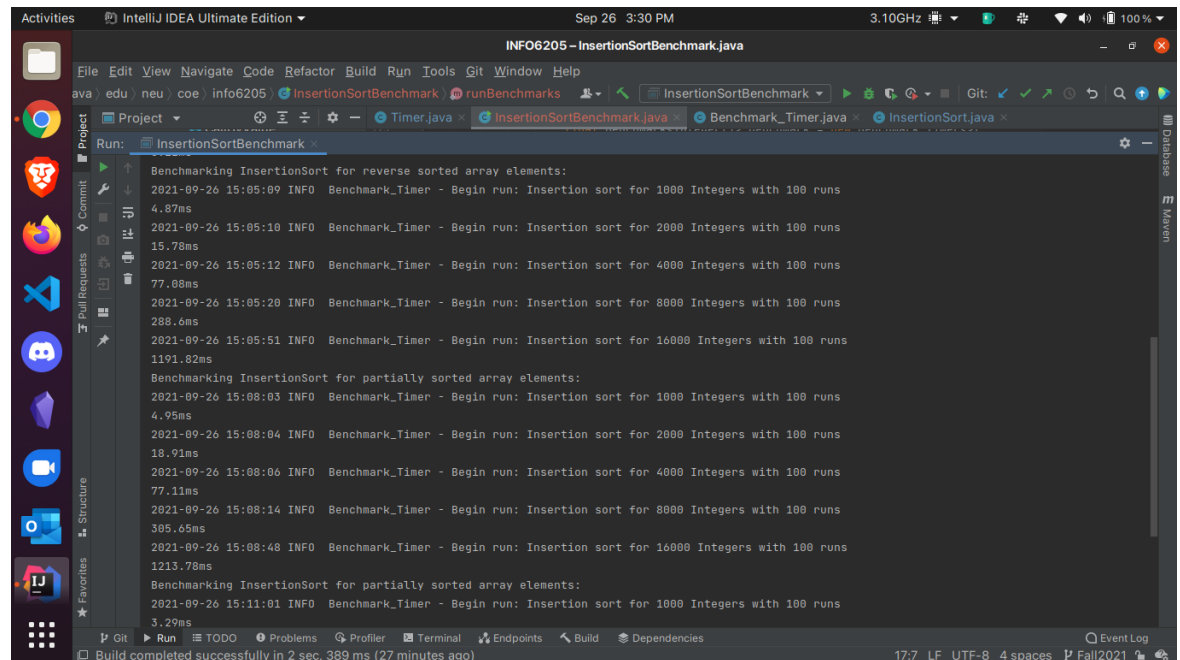
- Evidence to support the conclusion:

1. The output of the program:



The screenshot shows the IntelliJ IDEA interface with the 'Run' console displaying the output of the 'InsertionSortBenchmark.java' program. The output is as follows:

```
Run: InsertionSortBenchmark
/usr/lib/jvm/java-11.0-openjdk-amd64/bin/java ...
Benchmarking InsertionSort for random array elements:
2021-09-26 15:03:39 INFO Benchmark_Timer - Begin run: Insertion sort for 1000 Integers with 100 runs
3.42ms
2021-09-26 15:03:40 INFO Benchmark_Timer - Begin run: Insertion sort for 2000 Integers with 100 runs
11.09ms
2021-09-26 15:03:41 INFO Benchmark_Timer - Begin run: Insertion sort for 4000 Integers with 100 runs
35.0ms
2021-09-26 15:03:45 INFO Benchmark_Timer - Begin run: Insertion sort for 8000 Integers with 100 runs
144.83ms
2021-09-26 15:04:01 INFO Benchmark_Timer - Begin run: Insertion sort for 16000 Integers with 100 runs
620.1ms
Benchmarking InsertionSort for sorted array elements:
2021-09-26 15:05:09 INFO Benchmark_Timer - Begin run: Insertion sort for 1000 Integers with 100 runs
0.01ms
2021-09-26 15:05:09 INFO Benchmark_Timer - Begin run: Insertion sort for 2000 Integers with 100 runs
0.03ms
2021-09-26 15:05:09 INFO Benchmark_Timer - Begin run: Insertion sort for 4000 Integers with 100 runs
0.05ms
2021-09-26 15:05:09 INFO Benchmark_Timer - Begin run: Insertion sort for 8000 Integers with 100 runs
0.06ms
2021-09-26 15:05:09 INFO Benchmark_Timer - Begin run: Insertion sort for 16000 Integers with 100 runs
0.12ms
Benchmarking InsertionSort for reverse sorted array elements:
2021-09-26 15:05:09 INFO Benchmark_Timer - Begin run: Insertion sort for 1000 Integers with 100 runs
0.12ms
Build completed successfully in 2 sec, 389 ms (27 minutes ago)
```

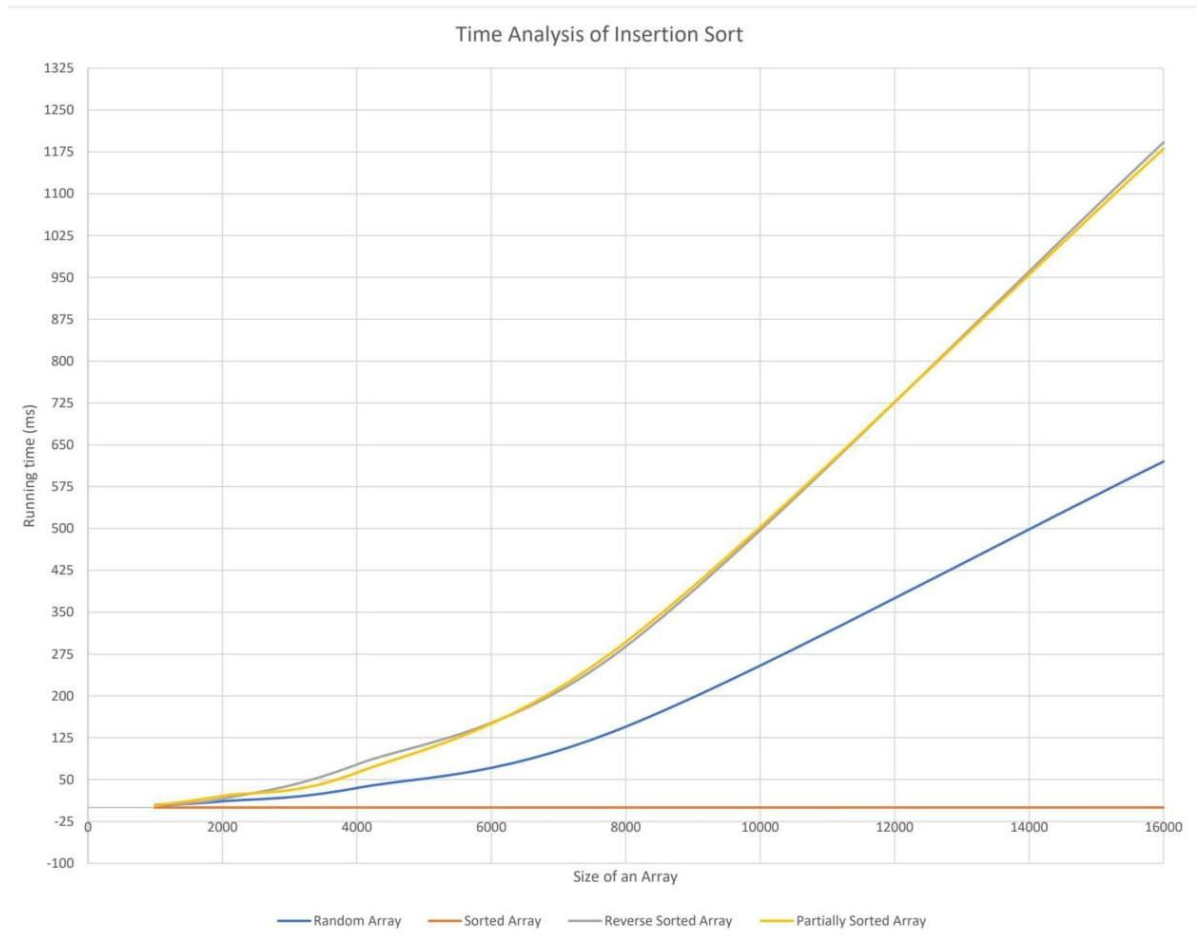


The screenshot shows the IntelliJ IDEA interface with the 'Run' console displaying the output of the 'InsertionSortBenchmark.java' program. The output is as follows:

```
Run: InsertionSortBenchmark
Benchmarking InsertionSort for reverse sorted array elements:
2021-09-26 15:05:09 INFO Benchmark_Timer - Begin run: Insertion sort for 1000 Integers with 100 runs
4.87ms
2021-09-26 15:05:10 INFO Benchmark_Timer - Begin run: Insertion sort for 2000 Integers with 100 runs
15.78ms
2021-09-26 15:05:12 INFO Benchmark_Timer - Begin run: Insertion sort for 4000 Integers with 100 runs
77.88ms
2021-09-26 15:05:20 INFO Benchmark_Timer - Begin run: Insertion sort for 8000 Integers with 100 runs
288.0ms
2021-09-26 15:05:51 INFO Benchmark_Timer - Begin run: Insertion sort for 16000 Integers with 100 runs
1191.82ms
Benchmarking InsertionSort for partially sorted array elements:
2021-09-26 15:08:03 INFO Benchmark_Timer - Begin run: Insertion sort for 1000 Integers with 100 runs
4.95ms
2021-09-26 15:08:04 INFO Benchmark_Timer - Begin run: Insertion sort for 2000 Integers with 100 runs
18.91ms
2021-09-26 15:08:06 INFO Benchmark_Timer - Begin run: Insertion sort for 4000 Integers with 100 runs
77.11ms
2021-09-26 15:08:14 INFO Benchmark_Timer - Begin run: Insertion sort for 8000 Integers with 100 runs
395.45ms
2021-09-26 15:08:48 INFO Benchmark_Timer - Begin run: Insertion sort for 16000 Integers with 100 runs
1213.78ms
Benchmarking InsertionSort for partially sorted array elements:
2021-09-26 15:11:01 INFO Benchmark_Timer - Begin run: Insertion sort for 1000 Integers with 100 runs
3.29ms
Build completed successfully in 2 sec, 389 ms (27 minutes ago)
```

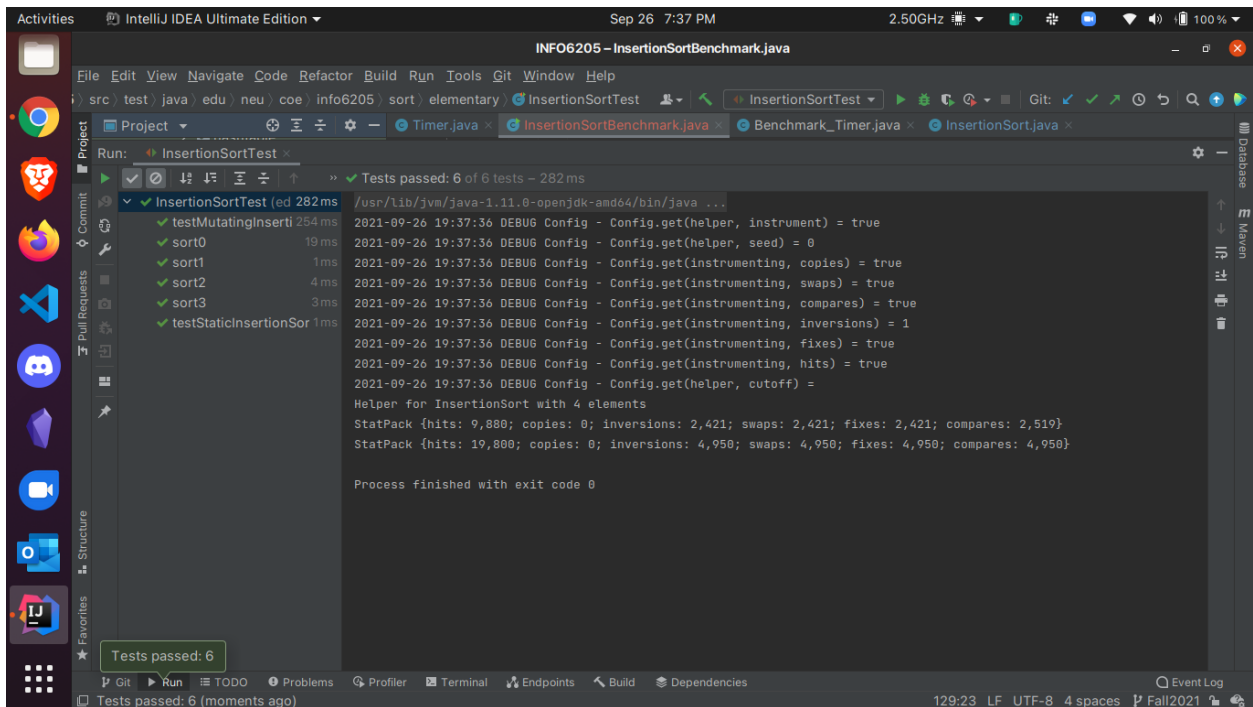
## 2. Graphical Representation:

N		Random Array	Sorted Array	Reverse Sorted Array	Partially Sorted Array
1000	Raw Time	3.42ms	0.01ms	4.87ms	3.29ms
2000	Raw Time	11.09ms	0.03ms	15.75ms	20.65ms
4000	Raw Time	35.00ms	0.05ms	77.08ms	62.42ms
8000	Raw Time	144.83ms	0.06ms	288.6ms	296.56ms
16000	Raw Time	620.10ms	0.12ms	1191.82ms	1180.41ms



- **Unit Tests Results:**

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Activities IntelliJ IDEA Ultimate Edition Sep 26 7:37 PM 2.50GHz

INFO6205 - InsertionSortBenchmark.java

File Edit View Navigate Code Refactor Build Run Tools Git Window Help

src test java edu neu coe info6205 sort elementary InsertionSortTest InsertionSortBenchmark.java Benchmark\_Timer.java InsertionSort.java

Run: InsertionSortTest Tests passed: 6 of 6 tests - 282 ms

InsertionSortTest (ed 282 ms)

- testMutatingInsert 254 ms
- sort0 19 ms
- sort1 1 ms
- sort2 4 ms
- sort3 3 ms
- testStaticInsertionSort 1 ms

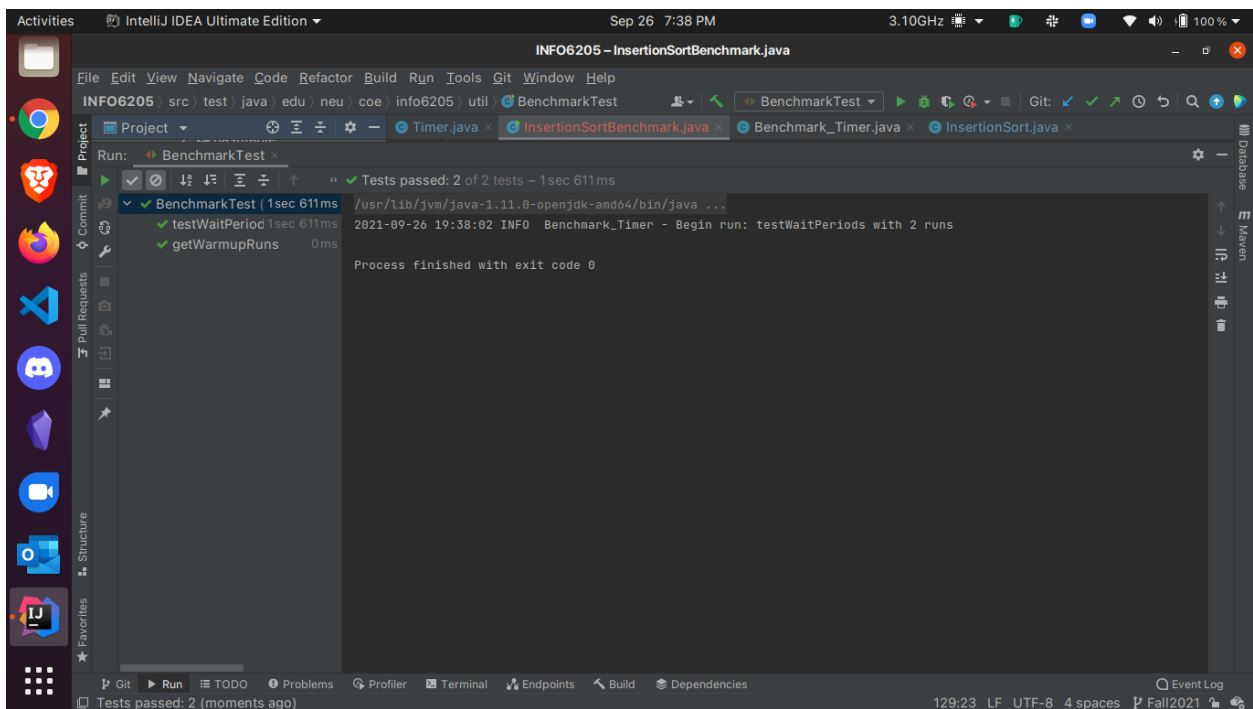
```
2021-09-26 19:37:36 DEBUG Config - Config.get(helper, instrument) = true
2021-09-26 19:37:36 DEBUG Config - Config.get(helper, seed) = 0
2021-09-26 19:37:36 DEBUG Config - Config.get(instrumenting, copies) = true
2021-09-26 19:37:36 DEBUG Config - Config.get(instrumenting, swaps) = true
2021-09-26 19:37:36 DEBUG Config - Config.get(instrumenting, compares) = true
2021-09-26 19:37:36 DEBUG Config - Config.get(instrumenting, inversions) = 1
2021-09-26 19:37:36 DEBUG Config - Config.get(instrumenting, fixes) = true
2021-09-26 19:37:36 DEBUG Config - Config.get(instrumenting, hits) = true
2021-09-26 19:37:36 DEBUG Config - Config.get(helper, cutoff) =
Helper for InsertionSort with 4 elements
StatPack {hits: 9,880; copies: 0; inversions: 2,421; swaps: 2,421; fixes: 2,421; compares: 2,519}
StatPack {hits: 19,800; copies: 0; inversions: 4,950; swaps: 4,950; fixes: 4,950; compares: 4,950}

Process finished with exit code 0
```

Tests passed: 6

Git Run TODO Problems Profiler Terminal Endpoints Build Dependencies

Tests passed: 6 (moments ago) 129:23 LF UTF-8 4 spaces Fall2021



Activities IntelliJ IDEA Ultimate Edition Sep 26 7:38 PM 3.10GHz

INFO6205 - InsertionSortBenchmark.java

File Edit View Navigate Code Refactor Build Run Tools Git Window Help

INFO6205 src test java edu neu coe info6205 util BenchmarkTest InsertionSortBenchmark.java Benchmark\_Timer.java InsertionSort.java

Run: BenchmarkTest Tests passed: 2 of 2 tests - 1sec 611ms

BenchmarkTest (1sec 611ms)

- testWaitPeriod 1sec 611ms
- getWarmupRuns 0ms

```
2021-09-26 19:38:02 INFO Benchmark_Timer - Begin run: testWaitPeriods with 2 runs

Process finished with exit code 0
```

Tests passed: 2

Git Run TODO Problems Profiler Terminal Endpoints Build Dependencies

Tests passed: 2 (moments ago) 129:23 LF UTF-8 4 spaces Fall2021