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Program Structures & Algorithms

Spring 2021

Assignment No. 02

● Task

1. To implement three methods of a class called Timer. Timer is invoked from a class called Benchmark_Timer which implements the Benchmark interface.
2. Implement InsertionSort and run unit tests in InsertionSortTest.
3. Implement a main program to run the following benchmarks: measure the running times of this sort, using four different initial array ordering situations: random, ordered, partially ordered and reverse-ordered. Use the doubling method for choosing n and test for at least five values of n. Draw any conclusions from your observations regarding the order of growth.

● Output

1. Reversed Array

```
Run: Benchmark_Timer x
"C:\Program Files\Java\jdk1.8.0_271\bin\java.exe" ...
Length of Reversed array :: 1000
2021-02-04 09:15:59 INFO Benchmark_Timer - Begin run: InsertionSort for Reversed Array with 20 runs
3.6
Length of Reversed array :: 2000
2021-02-04 09:15:59 INFO Benchmark_Timer - Begin run: InsertionSort for Reversed Array with 20 runs
8.7
Length of Reversed array :: 4000
2021-02-04 09:16:00 INFO Benchmark_Timer - Begin run: InsertionSort for Reversed Array with 20 runs
38.8
Length of Reversed array :: 8000
2021-02-04 09:16:03 INFO Benchmark_Timer - Begin run: InsertionSort for Reversed Array with 20 runs
136.15
Length of Reversed array :: 16000
2021-02-04 09:16:11 INFO Benchmark_Timer - Begin run: InsertionSort for Reversed Array with 20 runs
570.45
Length of Reversed array :: 32000
2021-02-04 09:16:48 INFO Benchmark_Timer - Begin run: InsertionSort for Reversed Array with 20 runs
3276.95

Process finished with exit code 0
```

2. Random Array

```
Run: Benchmark_Timer x
"C:\Program Files\Java\jdk1.8.0_271\bin\java.exe" ...
Length of Random array :: 1000
2021-02-04 09:34:00 INFO Benchmark_Timer - Begin run: InsertionSort for Random Array with 20 runs
2.8
Length of Random array :: 2000
2021-02-04 09:34:01 INFO Benchmark_Timer - Begin run: InsertionSort for Random Array with 20 runs
9.8
Length of Random array :: 4000
2021-02-04 09:34:01 INFO Benchmark_Timer - Begin run: InsertionSort for Random Array with 20 runs
41.25
Length of Random array :: 8000
2021-02-04 09:34:04 INFO Benchmark_Timer - Begin run: InsertionSort for Random Array with 20 runs
136.4
Length of Random array :: 16000
2021-02-04 09:34:13 INFO Benchmark_Timer - Begin run: InsertionSort for Random Array with 20 runs
393.65
Length of Random array :: 32000
2021-02-04 09:34:39 INFO Benchmark_Timer - Begin run: InsertionSort for Random Array with 20 runs
2312.45

Process finished with exit code 0
```

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3. Ordered Array

```
Run: Benchmark_Timer x
"C:\Program Files\Java\jdk1.8.0_271\bin\java.exe" ...
Length of Ordered array :: 1000
2021-02-04 09:54:54 INFO Benchmark_Timer - Begin run: InsertionSort for Ordered Array with 20 runs
0.1
Length of Ordered array :: 2000
2021-02-04 09:54:54 INFO Benchmark_Timer - Begin run: InsertionSort for Ordered Array with 20 runs
0.05
Length of Ordered array :: 4000
2021-02-04 09:54:54 INFO Benchmark_Timer - Begin run: InsertionSort for Ordered Array with 20 runs
0.0
Length of Ordered array :: 8000
2021-02-04 09:54:54 INFO Benchmark_Timer - Begin run: InsertionSort for Ordered Array with 20 runs
0.05
Length of Ordered array :: 16000
2021-02-04 09:54:54 INFO Benchmark_Timer - Begin run: InsertionSort for Ordered Array with 20 runs
0.05
Length of Ordered array :: 32000
2021-02-04 09:54:54 INFO Benchmark_Timer - Begin run: InsertionSort for Ordered Array with 20 runs
0.2
Process finished with exit code 0
```

4. Partially Ordered Array

```
Run: Benchmark_Timer x
"C:\Program Files\Java\jdk1.8.0_271\bin\java.exe" ...
Length of Partially Ordered array :: 1000
2021-02-04 10:09:28 INFO Benchmark_Timer - Begin run: InsertionSort for Partially Ordered Array with 20 runs
1.6
Length of Partially Ordered array :: 2000
2021-02-04 10:09:28 INFO Benchmark_Timer - Begin run: InsertionSort for Partially Ordered Array with 20 runs
7.4
Length of Partially Ordered array :: 4000
2021-02-04 10:09:28 INFO Benchmark_Timer - Begin run: InsertionSort for Partially Ordered Array with 20 runs
10.9
Length of Partially Ordered array :: 8000
2021-02-04 10:09:29 INFO Benchmark_Timer - Begin run: InsertionSort for Partially Ordered Array with 20 runs
43.6
Length of Partially Ordered array :: 16000
2021-02-04 10:09:32 INFO Benchmark_Timer - Begin run: InsertionSort for Partially Ordered Array with 20 runs
163.05
Length of Partially Ordered array :: 32000
2021-02-04 10:09:42 INFO Benchmark_Timer - Begin run: InsertionSort for Partially Ordered Array with 20 runs
871.35
Process finished with exit code 0
```

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- **Conclusion:**

From the experiments carried out, it was observed for the different array types as:

Array Type	Order of Growth	Type of Analysis
Ordered Array	$O(N)$	Best Case
Partially Ordered Array	$O(N^2)$	Average Case
Random Array	$O(N^2)$	Worst Case
Reverse Array	$O(N^2)$	Worst Case

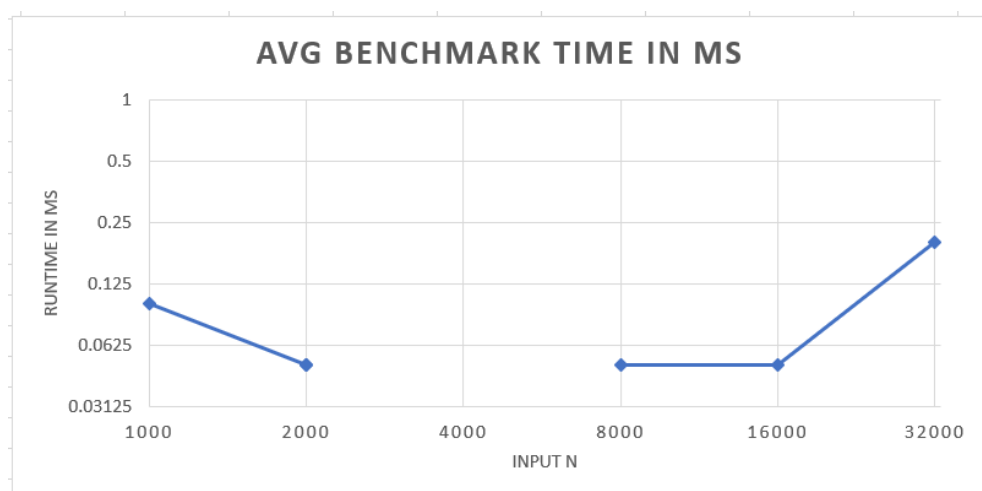
1. After benchmarking for Random Array and Reversed array, I observed that there was similar time taken to sort the array of size N.
2. For Partially Ordered Array, when compared to random and reverse array, it took less time while sorting as the array was partially sorted due to which the insertion sort was not going into the second for loop for the existing sorted portion.
3. Ordered Array took almost no time during the insertion sort.

- **Evidence to support conclusion and Graphical Representation:**

Below plotted is log log graph of the Benchmark time in ms and the input N.

1. Ordered Array

	A	B
1	Array Length	Avg Benchmark time in ms
2	1000	0.1
3	2000	0.05
4	4000	0
5	8000	0.05
6	16000	0.05
7	32000	0.2



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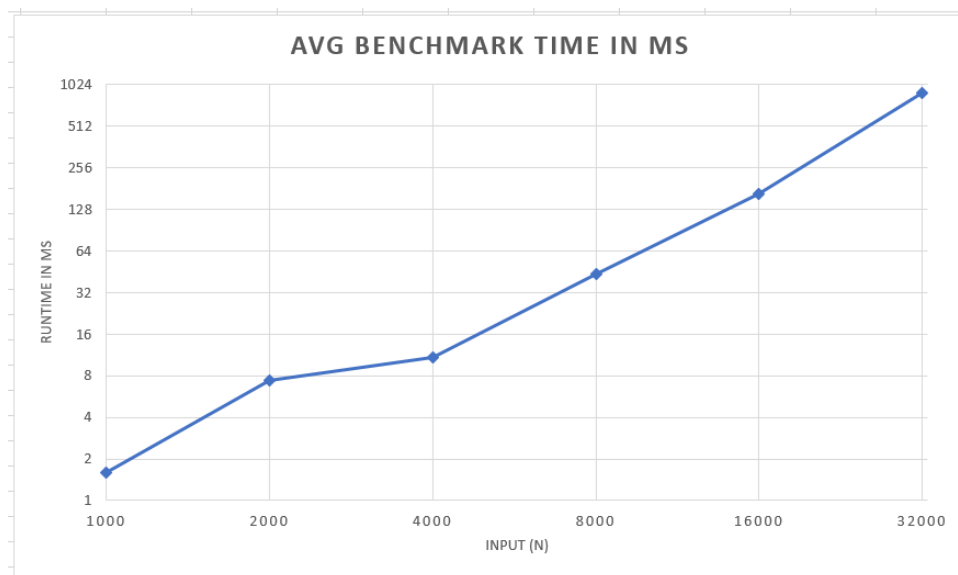
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2. Partially Ordered Array

	A	B
1	Array Length	Avg Benchmark time in ms
2	1000	1.6
3	2000	7.4
4	4000	10.9
5	8000	43.6
6	16000	163.05
7	32000	871.35



3. Random Array

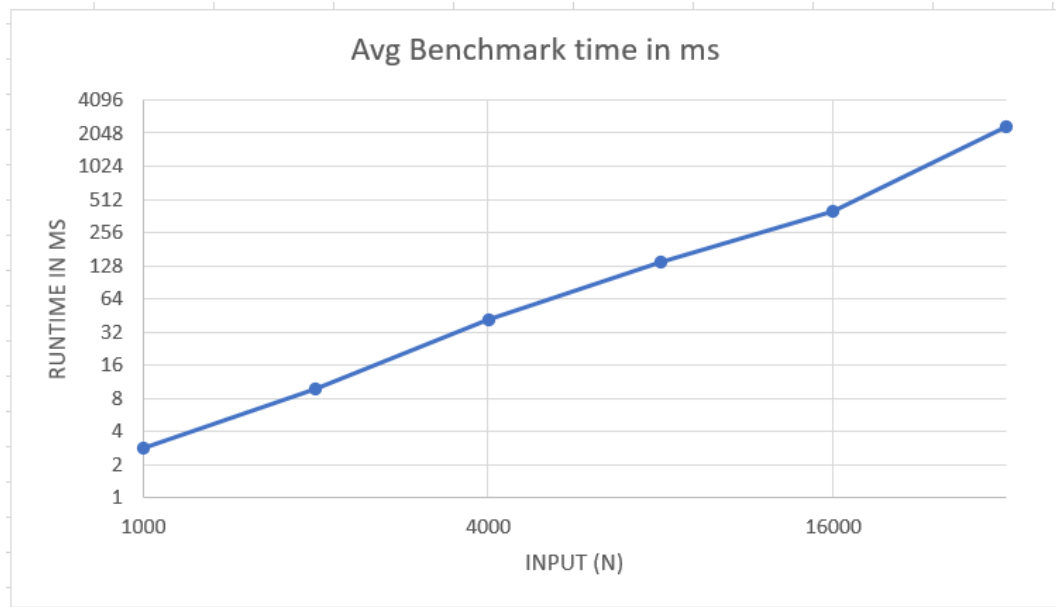
	A	B
1	Array Length	Avg Benchmark time in ms
2	1000	2.8
3	2000	9.8
4	4000	41.25
5	8000	136.4
6	16000	393.65
7	32000	2312.45

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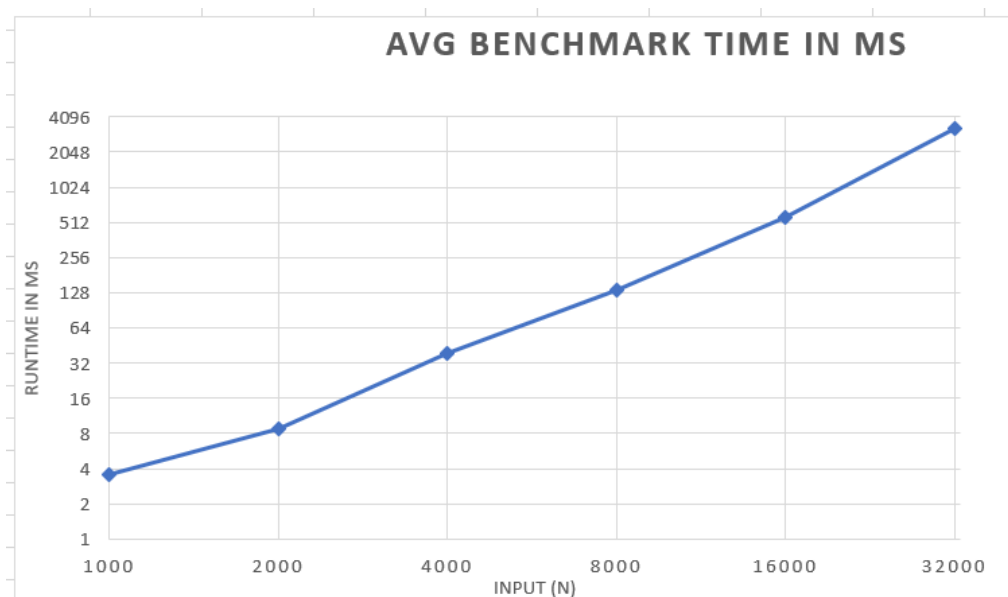
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4. Reversed Array

	A	B
1	Array Length	Avg Benchmark time in ms
2	1000	3.6
3	2000	8.7
4	4000	38.8
5	8000	136.15
6	16000	570.45
7	32000	3276.95



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- **Unit test results:**

Passed all test cases in BenchmarkTest, TimerTest and InsertionSortTest.

1. BenchmarkTest:



The screenshot shows the IDE's test runner for BenchmarkTest. The test suite passed 2 out of 2 tests in 1 s 674 ms. The tests are testWaitPeriods (1 s 674 ms) and getWarmupRuns (0 ms). The console output shows the test execution details and the process finished with exit code 0.

```
Run: BenchmarkTest x
Tests passed: 2 of 2 tests - 1 s 674 ms
BenchmarkTest (edu.neu.coe.info6205.util) 1 s 674 ms
  testWaitPeriods 1 s 674 ms
  getWarmupRuns 0 ms
"C:\Program Files\Java\jdk1.8.0_271\bin\java.exe" ...
2021-02-03 23:09:59 INFO Benchmark_Timer - Begin run: testWaitPeriods with 2 runs
Process finished with exit code 0
Tests passed: 2
```

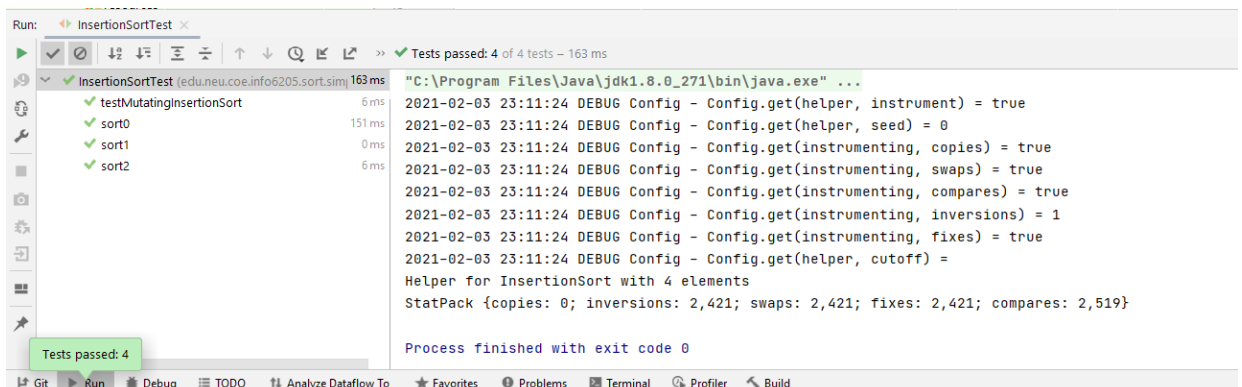
2. TimerTest:



The screenshot shows the IDE's test runner for TimerTest. The test suite passed 10 out of 10 tests in 2 s 373 ms. The tests are testPauseAndLapResume0 (303 ms), testPauseAndLapResume1 (316 ms), testLap (204 ms), testPause (202 ms), testStop (101 ms), testMillisecs (100 ms), testRepeat1 (294 ms), testRepeat2 (214 ms), testRepeat3 (539 ms), and testPauseAndLap (100 ms). The console output shows the test execution details and the process finished with exit code 0.

```
Run: TimerTest x
Tests passed: 10 of 10 tests - 2 s 373 ms
TimerTest (edu.neu.coe.info6205.util) 2 s 373 ms
  testPauseAndLapResume0 303 ms
  testPauseAndLapResume1 316 ms
  testLap 204 ms
  testPause 202 ms
  testStop 101 ms
  testMillisecs 100 ms
  testRepeat1 294 ms
  testRepeat2 214 ms
  testRepeat3 539 ms
  testPauseAndLap 100 ms
"C:\Program Files\Java\jdk1.8.0_271\bin\java.exe" ...
Process finished with exit code 0
Tests passed: 10
```

3. InsertionSortTest:



The screenshot shows the IDE's test runner for InsertionSortTest. The test suite passed 4 out of 4 tests in 163 ms. The tests are testMutatingInsertionSort (6 ms), sort0 (151 ms), sort1 (0 ms), and sort2 (6 ms). The console output shows the test execution details and the process finished with exit code 0.

```
Run: InsertionSortTest x
Tests passed: 4 of 4 tests - 163 ms
InsertionSortTest (edu.neu.coe.info6205.sort.sim) 163 ms
  testMutatingInsertionSort 6 ms
  sort0 151 ms
  sort1 0 ms
  sort2 6 ms
"C:\Program Files\Java\jdk1.8.0_271\bin\java.exe" ...
2021-02-03 23:11:24 DEBUG Config - Config.get(helper, instrument) = true
2021-02-03 23:11:24 DEBUG Config - Config.get(helper, seed) = 0
2021-02-03 23:11:24 DEBUG Config - Config.get(instrumenting, copies) = true
2021-02-03 23:11:24 DEBUG Config - Config.get(instrumenting, swaps) = true
2021-02-03 23:11:24 DEBUG Config - Config.get(instrumenting, compares) = true
2021-02-03 23:11:24 DEBUG Config - Config.get(instrumenting, inversions) = 1
2021-02-03 23:11:24 DEBUG Config - Config.get(instrumenting, fixes) = true
2021-02-03 23:11:24 DEBUG Config - Config.get(helper, cutoff) =
Helper for InsertionSort with 4 elements
StatPack {copies: 0; inversions: 2,421; swaps: 2,421; fixes: 2,421; compares: 2,519}
Process finished with exit code 0
Tests passed: 4
```