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Program Structures & Algorithms, Spring 2021
Assignment No 2

Task:

1. We are to implement three methods of a class called Timer. Please see the skeleton class that I created in the repository. Timer is invoked from a class called Benchmark_Timer which implements the Benchmark interface. To check the implementation the unit tests BenchmarkTest and TimerTest are used.
2. Implement InsertionSort (in the InsertionSort class) by simply looking up the insertion code used by Arrays.sort. You should use the helper.swap method although you could also just copy that from the same source code. You should of course run the unit tests in InsertionSortTest.
3. Implement a main program (or you could do it via your own unit tests) to actually 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. I suggest that your arrays to be sorted are of type Integer. 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.

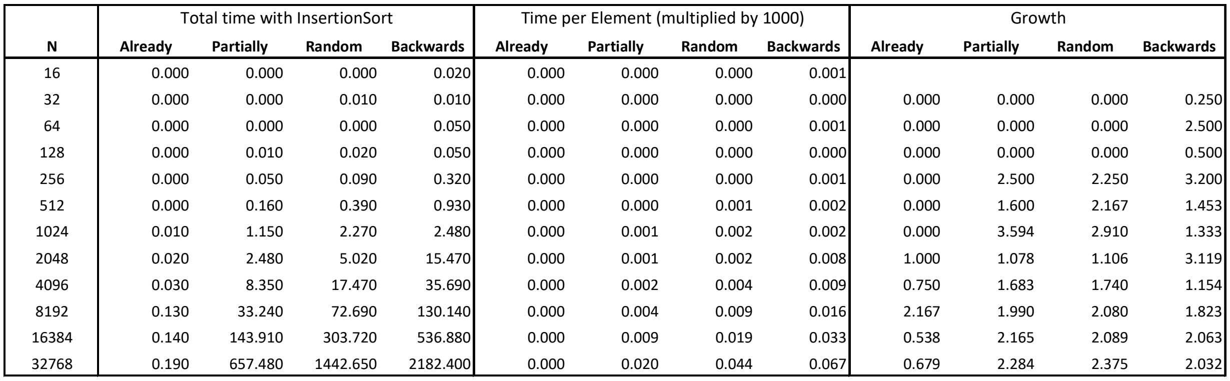
Output:

P.1 & P.2 were implemented as required. Please the unit tests below.

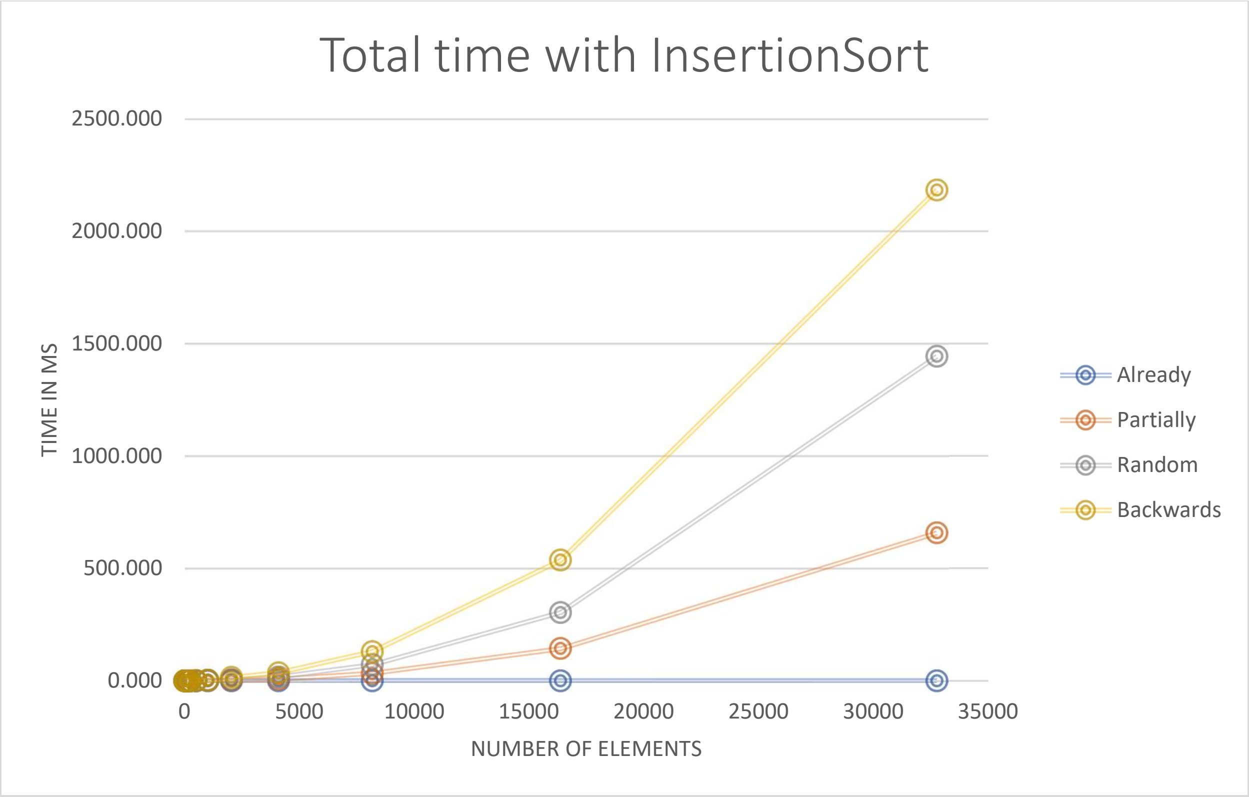
For P.3 – a new class is implemented:

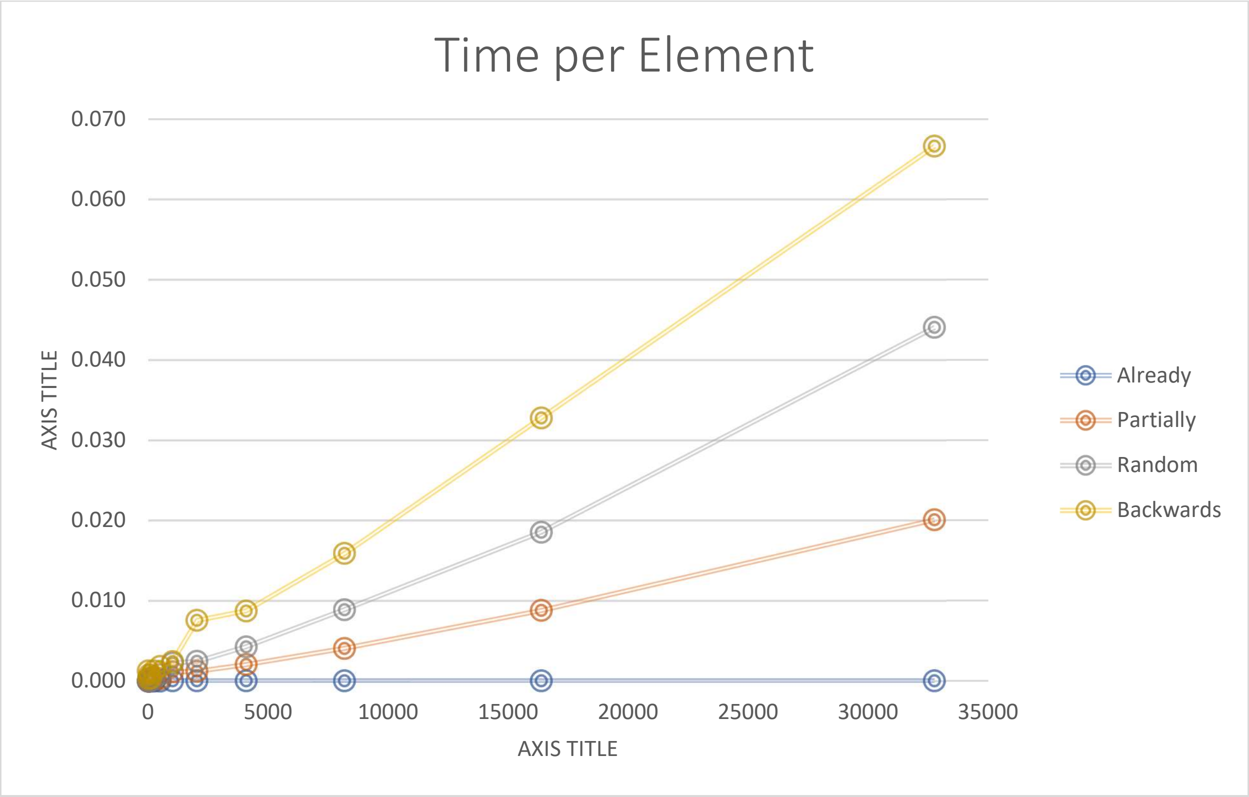
test -> java -> edu.neu.coe.info6205 -> sort -> simple -> CustomBenchmarks.class

It runs the InsertionSort for arrays starting with size of 2^4(16 elements) up to 2^15 (32k elements) under four different scenarios with random, ordered, partially-ordered and reverse-ordered arrays. The simulations run for 100 times each. We use Excel to show the output in a table and a chart.



	Total time with InsertionSort				Time per Element (multiplied by 1000)				Growth			
N	**Already**	**Partially**	**Random**	**Backwards**	**Already**	**Partially**	**Random**	**Backwards**	**Already**	**Partially**	**Random**	**Backwards**
16	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.001				
32	0.000	0.000	0.010	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250
64	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.001	0.000	0.000	0.000	2.500
128	0.000	0.010	0.020	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500
256	0.000	0.050	0.090	0.320	0.000	0.000	0.000	0.001	0.000	2.500	2.250	3.200
512	0.000	0.160	0.390	0.930	0.000	0.000	0.001	0.002	0.000	1.600	2.167	1.453
1024	0.010	1.150	2.270	2.480	0.000	0.001	0.002	0.002	0.000	3.594	2.910	1.333
2048	0.020	2.480	5.020	15.470	0.000	0.001	0.002	0.008	1.000	1.078	1.106	3.119
4096	0.030	8.350	17.470	35.690	0.000	0.002	0.004	0.009	0.750	1.683	1.740	1.154
8192	0.130	33.240	72.690	130.140	0.000	0.004	0.009	0.016	2.167	1.990	2.080	1.823
16384	0.140	143.910	303.720	536.880	0.000	0.009	0.019	0.033	0.538	2.165	2.089	2.063
32768	0.190	657.480	1442.650	2182.400	0.000	0.020	0.044	0.067	0.679	2.284	2.375	2.032

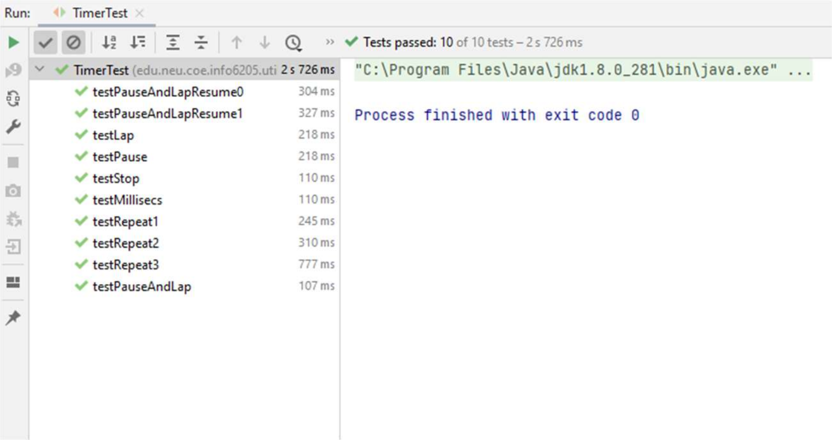

Total time with InsertionSort
TIME IN MS
2500.000
2000.000
1500.000
1000.000
500.000
0.000
0
5000
10000
15000
20000
25000
30000
35000
NUMBER OF ELEMENTS
Already
Partially
Random
Backwards


Time per Element
AXIS TITLE
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
0
5000
10000
15000
20000
25000
30000
35000
AXIS TITLE
Already
Partially
Random
Backwards

Relationship Conclusion:

We can see that the time spent **per element** in worst case scenario **increases linearly** and looks like in worst case scenario we are getting O(N^2) complexity. Even though with Random and Partially sorted arrays we have slower growth, it is still far from constant.

Unit Test Results:

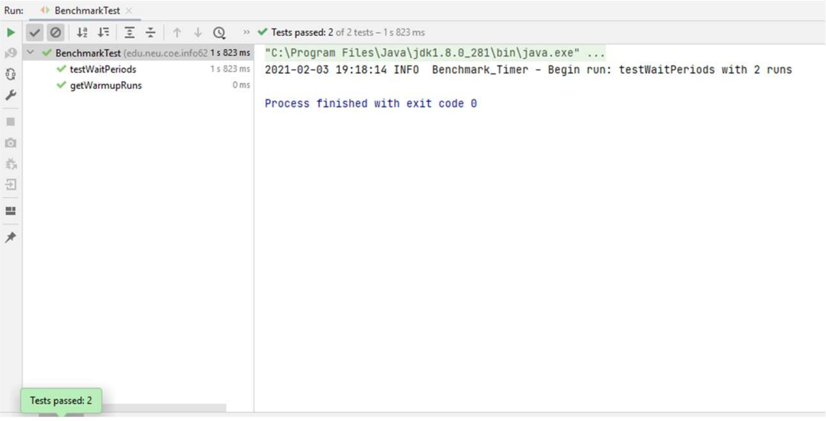


```
Tests passed: 10 of 10 tests – 2 s 726 ms

TimerTest (edu.neu.coe.info6205.uti 2 s 726 ms
    testPauseAndLapResume0      304 ms
    testPauseAndLapResume1      327 ms
    testLap                     218 ms
    testPause                   218 ms
    testStop                    110 ms
    testMillisecs               110 ms
    testRepeat1                 245 ms
    testRepeat2                 310 ms
    testRepeat3                 777 ms
    testPauseAndLap             107 ms
```

```
"C:\Program Files\Java\jdk1.8.0_281\bin\java.exe" ...

Process finished with exit code 0
```



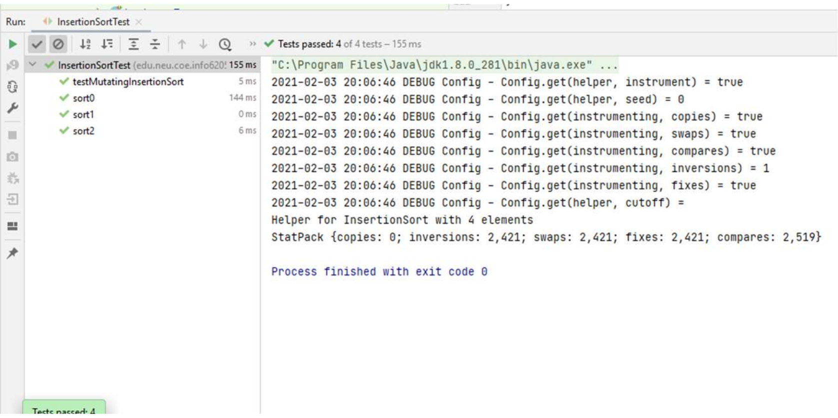
```
Tests passed: 2 of 2 tests – 1 s 823 ms

BenchmarkTest (edu.neu.coe.info62 1 s 823 ms
    testWaitPeriods     1 s 823 ms
    getWarmupRuns             0 ms
```

```
"C:\Program Files\Java\jdk1.8.0_281\bin\java.exe" ...
2021-02-03 19:18:14 INFO  Benchmark_Timer - Begin run: testWaitPeriods with 2 runs

Process finished with exit code 0
```

Tests passed: 2



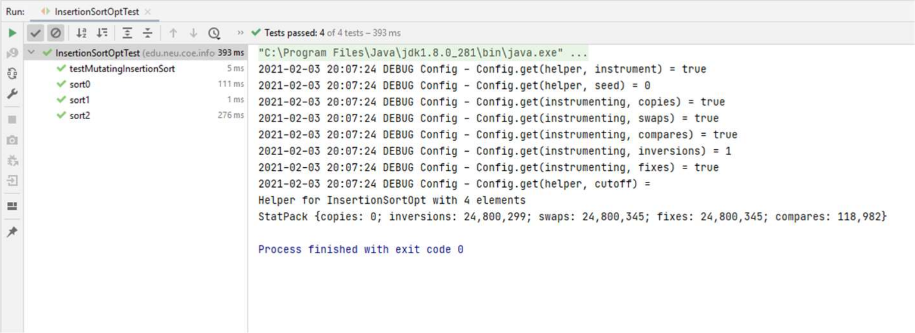
```
Tests passed: 4 of 4 tests – 155 ms

InsertionSortTest (edu.neu.coe.info620! 155 ms
    testMutatingInsertionSort    5 ms
    sort0                      144 ms
    sort1                        0 ms
    sort2                        6 ms
```

```
"C:\Program Files\Java\jdk1.8.0_281\bin\java.exe" ...
2021-02-03 20:06:46 DEBUG Config - Config.get(helper, instrument) = true
2021-02-03 20:06:46 DEBUG Config - Config.get(helper, seed) = 0
2021-02-03 20:06:46 DEBUG Config - Config.get(instrumenting, copies) = true
2021-02-03 20:06:46 DEBUG Config - Config.get(instrumenting, swaps) = true
2021-02-03 20:06:46 DEBUG Config - Config.get(instrumenting, compares) = true
2021-02-03 20:06:46 DEBUG Config - Config.get(instrumenting, inversions) = 1
2021-02-03 20:06:46 DEBUG Config - Config.get(instrumenting, fixes) = true
2021-02-03 20:06:46 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



```
✓ Tests passed: 4 of 4 tests – 393 ms

✓ InsertionSortOptTest (edu.neu.coe.info 393 ms
    ✓ testMutatingInsertionSort            5 ms
    ✓ sort0                              111 ms
    ✓ sort1                                1 ms
    ✓ sort2                              276 ms
```

```
"C:\Program Files\Java\jdk1.8.0_281\bin\java.exe" ...
2021-02-03 20:07:24 DEBUG Config - Config.get(helper, instrument) = true
2021-02-03 20:07:24 DEBUG Config - Config.get(helper, seed) = 0
2021-02-03 20:07:24 DEBUG Config - Config.get(instrumenting, copies) = true
2021-02-03 20:07:24 DEBUG Config - Config.get(instrumenting, swaps) = true
2021-02-03 20:07:24 DEBUG Config - Config.get(instrumenting, compares) = true
2021-02-03 20:07:24 DEBUG Config - Config.get(instrumenting, inversions) = 1
2021-02-03 20:07:24 DEBUG Config - Config.get(instrumenting, fixes) = true
2021-02-03 20:07:24 DEBUG Config - Config.get(helper, cutoff) =
Helper for InsertionSortOpt with 4 elements
StatPack {copies: 0; inversions: 24,800,299; swaps: 24,800,345; fixes: 24,800,345; compares: 118,982}

Process finished with exit code 0
```