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INFO 6205
Program Structures & Algorithms
Fall 2020
Assignment 2

Task

Complete the benchmarking & insertion sorting code. Further, draw conclusions from analyzing time complexity for the insertion sort.

Evidence

Running time (in milliseconds) of insertion sort for different types & sizes of array:

SIZE N	RANDOM T1	ORDERED T2	REVERSE ORDERED T3	PARTIALLY ORDERED T4
1000	1.589	0.008	2.018	0.766
2000	3.945	0.017	8.081	3.020
4000	16.069	0.033	34.046	12.344
8000	68.687	0.050	127.241	48.029
16000	257.170	0.094	526.254	191.821

It is evident that reverse ordered array displays the poor performance of insertion sort, hence the worst case. Ordered array provides the best case for insertion sort here.

The worst case of insertion sort has time complexity of $O(N^2)$, which can be proven by data analysis using log-log plot

N	LOG(N)	LOG(T3)
1000	9.965	1.013
2000	10.965	3.014
4000	11.965	5.089
8000	12.965	6.991
16000	13.965	9.036

Computing the slopes:

1. Between 2000 & 1000, (10.965 - 9.965) / (3.014 – 1.013) = 2.001
2. Between 4000 & 2000, (11.965 - 10.965) / (5.089 – 3.014) = 2.074
3. Between 8000 & 4000, (12.965 - 11.965) / (6.991 – 5.089) = 1.902
4. Between 16000 & 8000, (13.965 - 12.965) / (9.036 – 5.089) = 2.045

Average of slope = 2.001, which seems to converge to 2 and proves that worst case complexity is of order 2 i.e. $O(N^2)$

Conclusion

Time complexities best, average and worst case for insertion are $O(N)$, $O(N^2)$ and $O(N^2)$ respectively.

Screenshots

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N = 1000 & Average Time for :
Randomly sorted  = 1.58965688 ms
Already sorted   = 0.00881554 ms
Partially sorted = 0.76650988 ms
Reverse sorted   = 2.0188444999999997 ms
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N = 2000 & Average Time for :
Randomly sorted  = 3.945458 ms
Already sorted   = 0.017050319999999997 ms
Partially sorted = 3.02005072 ms
Reverse sorted   = 8.081223959999999 ms
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N = 4000 & Average Time for :
Randomly sorted  = 16.0696715 ms
Already sorted   = 0.03311348 ms
Partially sorted = 12.3441095 ms
Reverse sorted   = 34.046186119999994 ms
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N = 8000 & Average Time for :
Randomly sorted  = 68.68764158 ms
Already sorted   = 0.05017938 ms
Partially sorted = 48.029020259999996 ms
Reverse sorted   = 127.24122663999998 ms
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N = 16000 & Average Time for :
Randomly sorted  = 257.17019958 ms
Already sorted   = 0.09454416 ms
Partially sorted = 191.821581 ms
Reverse sorted   = 526.25479078 ms
```

Figure 1 Running times for insertion sort with different array

Figure 2 Execution of insertion sort unit tests

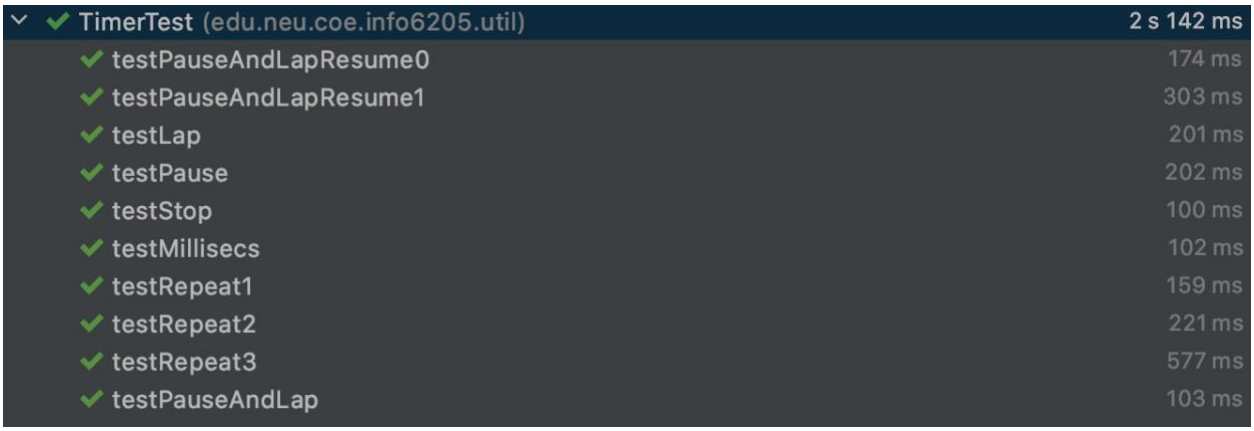

Figure 3 Execution of timer unit tests

Figure 4 Execution of benchmarking unit tests