CS202

Section:03

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HW1

Question1

a)$f(n)=5n^3+4n^2+10$ is $O(n^4)$

There are two positive constants: **c** and $\mathbf{n_0}$ such that:

$0 \leq 5n^3 \leq cn^4$ for all $n \geq n_0$

Choose $c = 2$ and $n_0 = 1$

Then, $5n^3 \leq 2n^4$ for all $n \geq 1$

Or, choose $c = 1$ and $n_0 = 2$

Then, $5n^3 \leq n^4$ for all $n \geq 2$

b)Insertion Sort

- [24, 8, 51, 28, 20, 29, 21, 17, 38, 27]

Step1- 24 **|8** 51 28 20 29 21 17 38 27. key:8

Step2- 8 24 **|51** 28 20 29 21 17 38 27. key:51

Step3- 8 24 51 **|28** 20 29 21 17 38 27. key:28

Step4- 8 24 28 51 **|20** 29 21 17 38 27. key:20

Step5- 8 20 24 28 51 **|29** 21 17 38 27. key:29

Step6- 8 20 24 28 29 51 **|21** 17 38 27. key:21

Step7- 8 20 21 24 28 29 51 **|17** 38 27. key:17

Step8- 8 17 20 21 24 28 29 51 **|38** 27. key:38

Step9- 8 17 20 21 24 28 29 38 51 **|27.** key:27

Step10- 8 17 20 21 24 27 28 29 38 51 | sorted.

Bubble Sort

- [24, 8, 51, 28, 20, 29, 21, 17, 38, 27]

First pass	Comparisons
24 8 51 28 20 29 21 17 38 27 **-|**	24 and 8
8 **24 51** 28 20 29 21 17 38 27 **-|**	24 and 51
8 24 **51 28** 20 29 21 17 38 27 **-|**	51 and 28
8 24 28 **51 20** 29 21 17 38 27 **-|**	51 and 20
8 24 28 20 **51 29** 21 17 38 27 **-|**	51 and 29
8 24 28 20 29 **51 21** 17 38 27 **-|**	51 and 21
8 24 28 20 29 21 **51 17** 38 27 **-|**	51 and 17
8 24 28 20 29 21 17 **51 38** 27 **-|**	51 and 38
8 24 28 20 29 21 17 38 **51 27 -|**	51 and 27
8 24 28 20 29 21 17 38 27 **-| 51**	pass 1 ends

Second pass	Comparisons
8 24 28 20 29 21 17 38 27 **-|** 51	8 and 24
8 **24 28** 20 29 21 17 38 27 **-|** 51	24 and 28
8 24 **28 20** 29 21 17 38 27 **-|** 51	28 and 20
8 24 20 **28 29** 21 17 38 27 **-|** 51	28 and 29
8 24 20 28 **29 21** 17 38 27 **-|** 51	29 and 21
8 24 20 28 21 **29 17** 38 27 **-|** 51	29 and 17
8 24 20 28 21 17 **29 38** 27 **-|** 51	29 and 38
8 24 20 28 21 17 29 **38 27 -|** 51	38 and 27
8 24 20 28 21 17 29 27 **-| 38** 51	pass 2 ends

Third pass	Comparisons
8 24 20 28 21 17 29 27 **-|** 38 51	8 and 24
8 **24 20** 28 21 17 29 27 **-|** 38 51	24 and 20
8 20 **24 28** 21 17 29 27 **-|** 38 51	24 and 28
8 20 24 **28 21** 17 29 27 **-|** 38 51	28 and 21
8 20 24 21 **28 17** 29 27 **-|** 38 51	28 and 17
8 20 24 21 17 **28 29** 27 **-|** 38 51	28 and 29
8 20 24 21 17 28 **29 27 -|** 38 51	29 and 27
8 20 24 21 17 28 27 **| 29** 38 51	pass 3 ends

Fourth pass	Comparisons
8 20 24 21 17 28 27 **|** 29 38 51	8 and 20
8 **20 24** 21 17 28 27 **|** 29 38 51	20 and 24
8 20 **24 21** 17 28 27 **|** 29 38 51	24 and 21

8 20 21 **24 17** 28 27 | 29 38 51 24 and 17

8 20 21 17 **24 28** 27 | 29 38 51 24 and 28

8 20 21 17 24 **28 27** | 29 38 51 28 and 27

8 20 21 17 24 27 | **28** 29 38 51 pass 4 ends

Fifth pass Comparisons

8 20 21 17 24 27 | 28 29 38 51 8 and 20

8 **20 21** 17 24 27 | 28 29 38 51 20 and 21

8 20 **21 17** 24 27 | 28 29 38 51 21 and 17

8 20 17 **21 24** 27 | 28 29 38 51 21 and 24

8 20 17 21 **24 27** | 28 29 38 51 24 and 27

8 20 17 21 24 | **27** 28 29 38 51 pass 5 ends

Sixth pass Comparisons

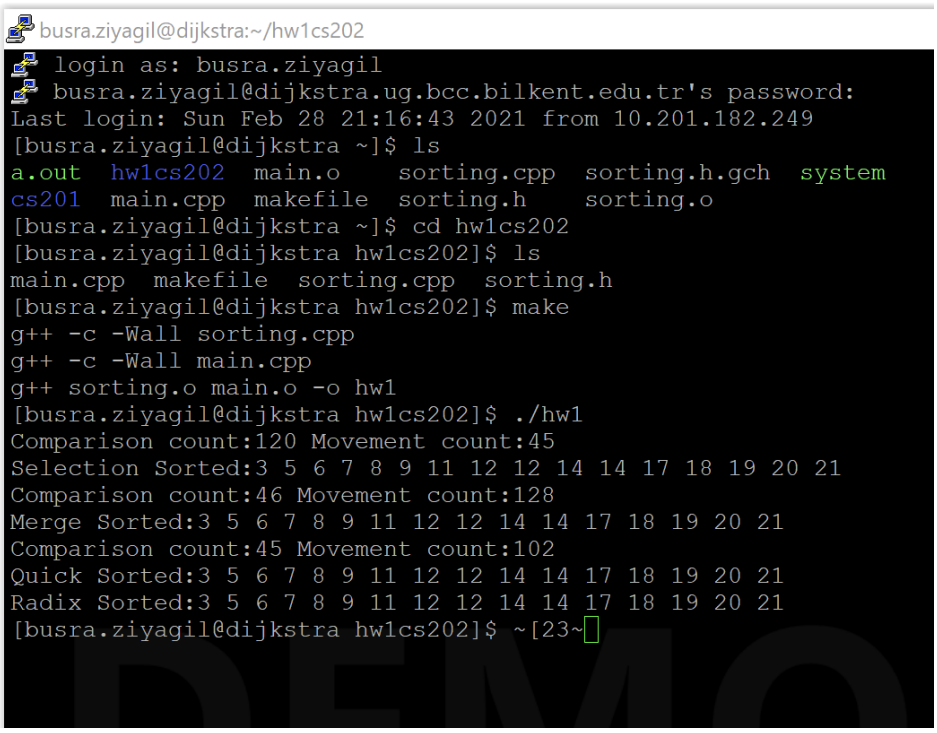
8 20 17 21 24 | 27 28 29 38 51 8 and 20

8 **20 17** 21 24 | 27 28 29 38 51 20 and 17

| 8 17 20 21 24 27 28 29 38 51 sorted

Question2

C)



```
Comparison count:120 Movement count:45
Selection Sorted:3 5 6 7 8 9 11 12 12 14 14 17 18 19 20 21
Comparison count:46 Movement count:128
Merge Sorted:3 5 6 7 8 9 11 12 12 14 14 17 18 19 20 21
Comparison count:45 Movement count:102
Quick Sorted:3 5 6 7 8 9 11 12 12 14 14 17 18 19 20 21
Radix Sorted:3 5 6 7 8 9 11 12 12 14 14 17 18 19 20 21
--------------------------------------------------
Analysis of Selection Sort
Random arrays
              Array Size              Elapsed time                compCount                moveCount
                    6000                     32978                 17997000                    17997
                   10000                     87997                 49995000                    29997
                   14000                    179042                 97993000                    41997
                   18000                    282600                161991000                    53997
                   22000                    415647                241989000                    65997
                   26000                    603975                337987000                    77997
                   30000                    800349                449985000                    89997
Ascending arrays
              Array Size              Elapsed time                compCount                moveCount
                    6000                     37322                 17997000                    17997
                   10000                    104600                 49995000                    29997
                   14000                    201183                 97993000                    41997
                   18000                    334909                161991000                    53997
                   22000                    485268                241989000                    65997
                   26000                    691458                337987000                    77997
                   30000                    912888                449985000                    89997
Descending arrays
              Array Size              Elapsed time                compCount                moveCount
                    6000                     34420                 17997000                    17997
                   10000                     95802                 49995000                    29997
                   14000                    188445                 97993000                    41997
                   18000                    309508                161991000                    53997
                   22000                    465657                241989000                    65997
                   26000                    649860                337987000                    77997
                   30000                    854058                449985000                    89997
--------------------------------------------------
Analysis of Merge Sort
```

d)

```
                   22000                    465657                241989000                    65997
                   26000                    649860                337987000                    77997
                   30000                    854058                449985000                    89997
--------------------------------------------------
Analysis of Merge Sort
Random arrays
              Array Size              Elapsed time                compCount                moveCount
                    6000                     1010                    67798                   151616
                   10000                     1778                   120470                   267232
                   14000                     2339                   175271                   387232
                   18000                     3363                   231974                   510464
                   22000                     3892                   290200                   638464
                   26000                     4938                   348815                   766464
                   30000                     5292                   408764                   894464
Ascending arrays
              Array Size              Elapsed time                compCount                moveCount
                    6000                      693                    39152                   151616
                   10000                      938                    69008                   267232
                   14000                     1271                    99360                   387232
                   18000                     1552                   130592                   510464
                   22000                     1953                   165024                   638464
                   26000                     2625                   197072                   766464
                   30000                     2819                   227728                   894464
Descending arrays
              Array Size              Elapsed time                compCount                moveCount
                    6000                      538                    36656                   151616
                   10000                      870                    64608                   267232
                   14000                     1214                    94256                   387232
                   18000                     1639                   124640                   510464
                   22000                     2112                   154208                   638464
                   26000                     2290                   186160                   766464
                   30000                     2648                   219504                   894464
--------------------------------------------------
Analysis of Quick Sort
Random arrays
              Array Size              Elapsed time                compCount                moveCount
                    6000                      678                    92744                   140373
                   10000                     1479                   154772                   268622
```

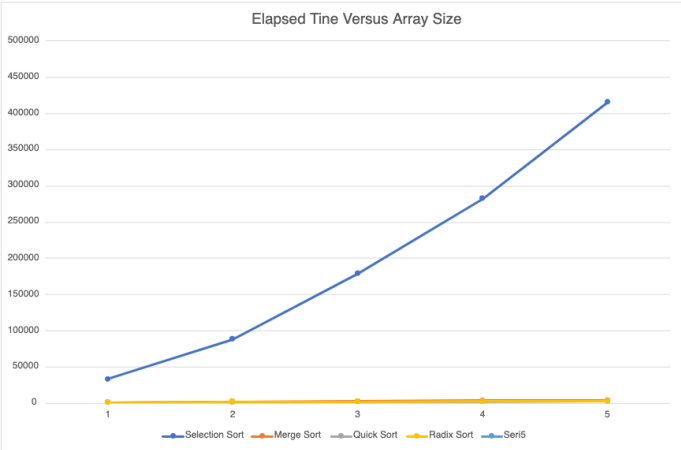
```
                26000                    2290                  188180                  788484
                30000                    2648                  219504                  894464
-------------------------------------------------
Analysis of Quick Sort
Random arrays
            Array Size             Elapsed time                compCount                moveCount
                 6000                      678                    92744                   140373
                10000                     1479                   154772                   268622
                14000                     1723                   222665                   399328
                18000                     2150                   302320                   458481
                22000                     2800                   364644                   620521
                26000                     3442                   449474                   731269
                30000                     4101                   518744                   909868
Ascending arrays
            Array Size             Elapsed time                compCount                moveCount
                 6000                    26522                 17997000                    23996
                10000                    76533                 49995000                    39996
                14000                   147459                 97993000                    55996
                18000                   238944                161991000                    71996
                22000                   353009                241989000                    87996
                26000                   484058                337987000                   103996
                30000                   655075                449985000                   119996
Descending arrays
            Array Size             Elapsed time                compCount                moveCount
                 6000                    61605                 17997000                  27023996
                10000                   174148                 49995000                  75039996
                14000                   340361                 97993000                 147055996
                18000                   515529                161991000                 243071996
                22000                   787857                241989000                 363087996
                26000                  1130880                337987000                 507103996
                30000                  1532988                449985000                 675119996
-------------------------------------------------
Analysis of Radix Sort
            Array Size             Elapsed time
Random arrays
            Array Size            Elapsed time
                 6000                      725
                10000                     1809
                14000                     2072
```

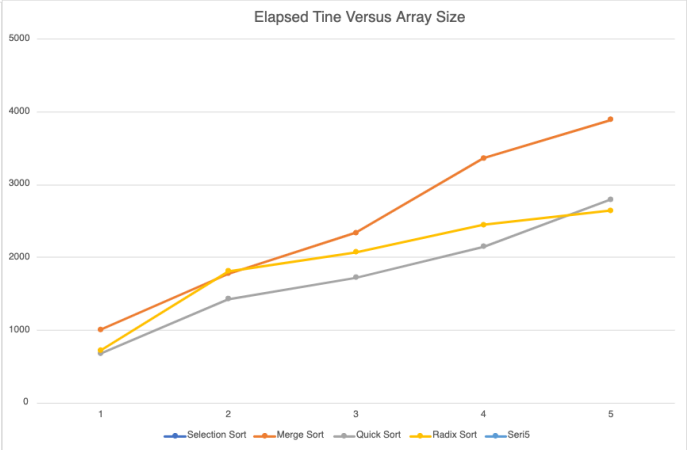
```
                14000                   340361                 97993000                 147055996
                18000                   515529                161991000                 243071996
                22000                   787857                241989000                 363087996
                26000                  1130880                337987000                 507103996
                30000                  1532988                449985000                 675119996
-------------------------------------------------
Analysis of Radix Sort
            Array Size             Elapsed time
Random arrays
            Array Size            Elapsed time
                 6000                      725
                10000                     1809
                14000                     2072
                18000                     2448
                22000                     2646
                26000                     4268
                30000                     3637
Ascending arrays
            Array Size            Elapsed time
                 6000                      725
                10000                     1636
                14000                     1848
                18000                     2387
                22000                     2587
                26000                     4104
                30000                     3498
Descending arrays
            Array Size            Elapsed time
                 6000                      725
                10000                     1599
                14000                     1826
                18000                     2342
                22000                     2592
                26000                     4012
                30000                     3506
Program ended with exit code: 0
```

All Output ⇕

Question3

a)





Note: In order to see the comparison between sorting algorithms clearly I have added two graphs instead of one. Because difference between selection sort and other algorithms was vast.

Selection sort algorithm always uses quadratic time which is $O(n^2)$ to complete its work. As it can be observed from the graph it is obviously the least fast algorithm. It has taken the most time because it had made every data move and every comparison possible to complete running. The time algorithm had taken did not diverge that much because the moves stayed the same no matter how array is sorted before. Its empirical results are in harmony with theorical ones.

Merge sort algorithm uses O(nlogn) in average of cases. It is a recursive algorithm whose strategy is divide, conquer and combine. It is slightly slower than quick sort and radix sort algorithm and it is probably due to its double memory usage. The time algorithm had taken diverges slightly and the best case happens when the array is sorted descendingly according to the results and its best case is still O(nlogn).

Quick sort algorithm uses O(nlogn) in average of cases. It is a recursive algorithm whose worst case is $O(n^2)$ .It is the fastest algorithm in most of the cases in the results. The time algorithm had taken diverges a lot and the best case happens when the array is not sorted so, random. According to the results and its best case is still O(nlogn).

Radix sort algorithm uses O(n) in average of cases which is linear time. The time taken do not change no matter how array is sorted. However, as it can be observed in results it is not the fastest algorithm. Actually, its graph is similar to O(nlogn). The result is a consequence of having many parallel loops and using n as ten times. Its empirical results differs from theorical values.