**Programming Assignment #1**

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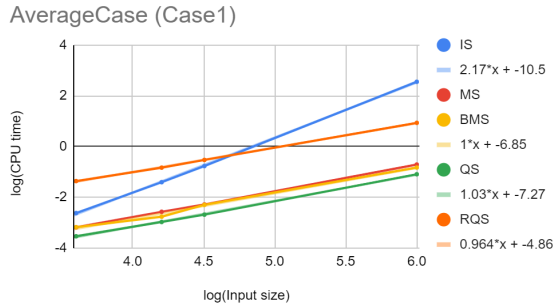
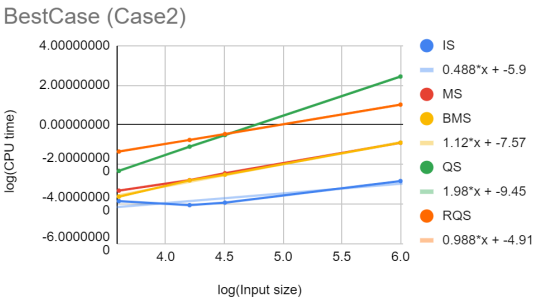
(a) Table of runtime and memory usage of five sorting algorithms. Trendline plot with slope calculation. Compare your slope with the complexity in the textbook. Please explain why or why not they match. (5%)

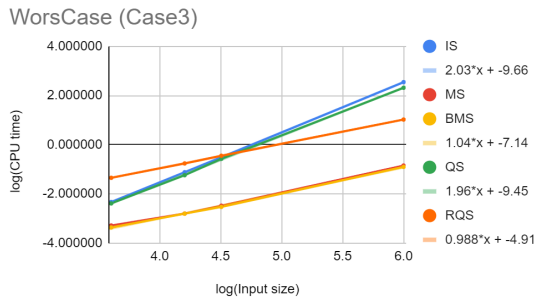
1. compare the running time of five sorting algorithms of different input sizes:
(run on my local terminal (ubuntu 22.04.4))

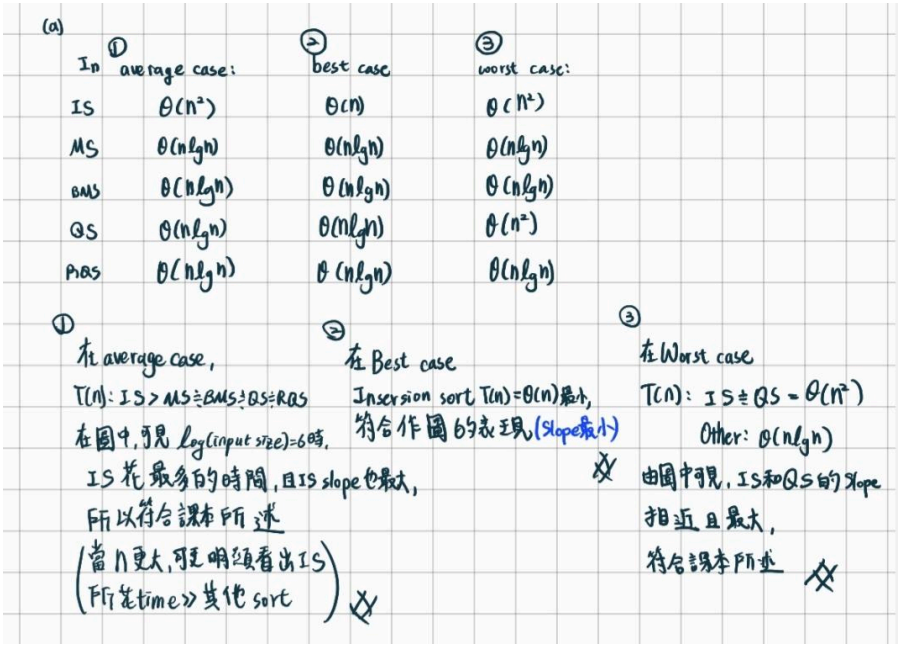
| Input size | IS | | MS | | BMS | | QS | | RQS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CPU time (s) | Memory (KB) | CPU time (s) | Memory (KB) | CPU time (s) | Memory (KB) | CPU time (s) | Memory (KB) | CPU time (s) | Memory (KB) |
| 4000.case2 | 0.000142 | 6,112 | 0.000480 | 6,224 | 0.000238 | 6,224 | 0.004745 | 6,112 | 0.045295 | 6,112 |
| 4000.case3 | 0.004697 | 6,112 | 0.000523 | 6,224 | 0.000435 | 6,224 | 0.004134 | 6,112 | 0.045344 | 6,112 |
| 4000.case1 | 0.002392 | 6,112 | 0.000655 | 6,224 | 0.000667 | 6,224 | 0.000291 | 6,112 | 0.043524 | 6,112 |
| 16000.case2 | 0.000089 | 6,232 | 0.001631 | 6,392 | 0.001595 | 6,392 | 0.080085 | 6,232 | 0.173656 | 6,232 |
| 16000.case3 | 0.076369 | 6,232 | 0.001598 | 6,392 | 0.001580 | 6,392 | 0.057948 | 6,488 | 0.174133 | 6,232 |
| 16000.case1 | 0.039331 | 6,232 | 0.002681 | 6,392 | 0.001715 | 6,392 | 0.001064 | 6,232 | 0.147342 | 6,232 |
| 32000.case2 | 0.000119 | 6,364 | 0.003626 | 6,432 | 0.003060 | 6,432 | 0.307980 | 6,364 | 0.345897 | 6,364 |
| 32000.case3 | 0.308955 | 6,364 | 0.003340 | 6,432 | 0.002980 | 6,432 | 0.268444 | 6,920 | 0.357056 | 6,364 |
| 32000.case1 | 0.170322 | 6,364 | 0.005224 | 6,432 | 0.005045 | 6,432 | 0.002070 | 6,364 | 0.296852 | 6,364 |
| 1000000.case2 | 0.001465 | 12,320 | 0.124430 | 18,464 | 0.126177 | 18,464 | 276.094000 | 12,320 | 10.538700 | 12,320 |
| 1000000.case3 | 350.810000 | 12,320 | 0.142728 | 18,464 | 0.125925 | 18,464 | 206.598000 | 24,172 | 10.571300 | 12,320 |
| 1000000.case1 | 356.737000 | 12,320 | 0.195093 | 18,464 | 0.149227 | 18,464 | 0.080871 | 12,320 | 8.591780 | 12,320 |

2. In your report, plot the trendline of five sorting algorithms to show the growth of run time as a function of input size, and try to analyze the slopes of the curves as well as their relation:
    - slope is on each figure
    - Note: 在 Average case, 在input size變大的時候, insersion sort 會變得比其他sort慢






(b) Comparison between MS and BMS, including runtime difference and explanation. (5%)
BMS因為沒有recursuve function, 所以可以避免來自iteration的overhead, 所以會比MS快一些,, 但這個快是很微小的, 兩者在各個case的時間複雜度都為nlgn。由圖上可見MS和BMS在三個case上的速度差異不大, 趨勢線幾乎相同。

(c) Comparison between QS and RQS, including runtime difference and explanation. (5%)
RQS在worst case 的時間複雜度為nlgn, QS在worst case 的時間複雜度為n^2。因為QS每次partition因為都選擇第一個index去做partition, 在worst case(reverse order)時, 每次被選作為partition者都為最大者, 導致每次partition時間複雜度只能-1, 所以時間複雜度為n^2。而RQS是隨機選擇任意index作為partition, 所以不會受到reverse order影響, 時間複雜度維持在nlogn

(d) Data structure used and other findings in this programming assignment. (5%)
[討論1] why quick sort have same time tendency as insertion sort in worst case?
[Ans] 因為Quick sort 的一般partition是拿一段的第一個為標兵(作為partition用), 所以當worst case(reverse order) 時, 每次剛好都會取道最大的那個為標兵, 所以每次partition都分成1:n-1跟n的堆, 每次partition都只減少一個, 導致花的時間趨勢和insertion sort 會類似
[討論2] How to solve it?
[Ans]在做Quicksort之前先做一次洗牌(shuffle) 避免reverse order 的發生