

- 以下是在 edaunion port: 40051 執行和檢查的結果：

IS：

```
-bash-4.1$ ../utility/PA1_Result_Checker ../inputs/1000.case2.in ../outputs/1000.case1.out
-----
-                                     -
-           Algorithm                 -
-           2019   Fall               -
-           PA1 Result Checker        -
-                                     -
-----

Congratulations: Your result passed this test!
-bash-4.1$ ./NTU_sort -IS ../inputs/4000.case1.in ../outputs/4000.case1.out
The total CPU time: 4.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -IS ../inputs/16000.case1.in ../outputs/16000.case1.out
The total CPU time: 71.989ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -IS ../inputs/32000.case1.in ../outputs/32000.case1.out
The total CPU time: 289.956ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -IS ../inputs/1000000.case1.in ../outputs/1000000.case1.out
The total CPU time: 284040ms
memory: 18668KB
```

```
-bash-4.1$ ./NTU_sort -IS ../inputs/4000.case2.in ../outputs/4000.case2.out
The total CPU time: 0ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -IS ../inputs/16000.case2.in ../outputs/16000.case2.out
The total CPU time: 0ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -IS ../inputs/32000.case2.in ../outputs/32000.case2.out
The total CPU time: 1ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -IS ../inputs/1000000.case2.in ../outputs/1000000.case2.out
The total CPU time: 1.999ms
memory: 18668KB
```

```
-bash-4.1$ ./NTU_sort -IS ../inputs/4000.case3.in ../outputs/4000.case3.out
The total CPU time: 8.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -IS ../inputs/16000.case3.in ../outputs/16000.case3.out
The total CPU time: 145.978ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -IS ../inputs/32000.case3.in ../outputs/32000.case3.out
The total CPU time: 580.911ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -IS ../inputs/1000000.case3.in ../outputs/1000000.case3.out
The total CPU time: 570150ms
memory: 18668KB
```

MS：

```
-bash-4.1$ ../utility/PA1_Result_Checker ../inputs/1000.case2.in ../outputs/1000.case1.out
-----
-                                     -
-           Algorithm                 -
-       2019   Fall                   -
-       PA1 Result Checker            -
-                                     -
-----

Congratulations: Your result passed this test!
-bash-4.1$ ./NTU_sort -MS ../inputs/4000.case1.in ../outputs/4000.case1.out
The total CPU time: 3.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -MS ../inputs/16000.case1.in ../outputs/16000.case1.out
The total CPU time: 13.998ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -MS ../inputs/32000.case1.in ../outputs/32000.case1.out
The total CPU time: 28.996ms
memory: 12836KB
-bash-4.1$ ./NTU_sort -MS ../inputs/1000000.case1.in ../outputs/1000000.case1.out
The total CPU time: 617.907ms
memory: 22760KB
```

```
-bash-4.1$ ./NTU_sort -MS ../inputs/4000.case2.in ../outputs/4000.case2.out
The total CPU time: 10.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -MS ../inputs/16000.case2.in ../outputs/16000.case2.out
The total CPU time: 11.998ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -MS ../inputs/32000.case2.in ../outputs/32000.case2.out
The total CPU time: 24.996ms
memory: 12836KB
-bash-4.1$ ./NTU_sort -MS ../inputs/1000000.case2.in ../outputs/1000000.case2.out
The total CPU time: 705.893ms
memory: 22760KB
```

```
-bash-4.1$ ./NTU_sort -MS ../inputs/4000.case3.in ../outputs/4000.case3.out
The total CPU time: 3ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -MS ../inputs/16000.case3.in ../outputs/16000.case3.out
The total CPU time: 11.998ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -MS ../inputs/32000.case3.in ../outputs/32000.case3.out
The total CPU time: 24.996ms
memory: 12836KB
-bash-4.1$ ./NTU_sort -MS ../inputs/1000000.case3.in ../outputs/1000000.case3.out
The total CPU time: 660.899ms
memory: 22760KB
```

QS :

```

-bash-4.1$ ../utility/PA1_Result_Checker ../inputs/1000.case2.in ../outputs/1000.case1.out
-----
Algorithm
2019 Fall
PA1 Result Checker
-----

Congratulations: Your result passed this test!
-bash-4.1$ ./NTU_sort -QS ../inputs/4000.case1.in ../outputs/4000.case1.out
The total CPU time: 4.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -QS ../inputs/16000.case1.in ../outputs/16000.case1.out
The total CPU time: 19.997ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -QS ../inputs/32000.case1.in ../outputs/32000.case1.out
The total CPU time: 39.994ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -QS ../inputs/1000000.case1.in ../outputs/1000000.case1.out
The total CPU time: 1389.79ms
memory: 18668KB

```

```

-bash-4.1$ ./NTU_sort -QS ../inputs/4000.case2.in ../outputs/4000.case2.out
The total CPU time: 4.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -QS ../inputs/16000.case2.in ../outputs/16000.case2.out
The total CPU time: 20.996ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -QS ../inputs/32000.case2.in ../outputs/32000.case2.out
The total CPU time: 40.994ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -QS ../inputs/1000000.case2.in ../outputs/1000000.case2.out
The total CPU time: 1403.79ms
memory: 18668KB

```

```

-bash-4.1$ ./NTU_sort -QS ../inputs/4000.case3.in ../outputs/4000.case3.out
The total CPU time: 4.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -QS ../inputs/16000.case3.in ../outputs/16000.case3.out
The total CPU time: 17.997ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -QS ../inputs/32000.case3.in ../outputs/32000.case3.out
The total CPU time: 35.995ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -QS ../inputs/1000000.case3.in ../outputs/1000000.case3.out
The total CPU time: 1373.79ms
memory: 18668KB

```

HS :

```

-bash-4.1$ ../utility/PA1_Result_Checker ../inputs/1000.case2.in ../outputs/1000.case1.out
-----
-                                     -
-      Algorithm                      -
-      2019  Fall                    -
-      PA1 Result Checker            -
-                                     -
-----

Congratulations: Your result passed this test!
-bash-4.1$ ./NTU_sort -HS ../inputs/4000.case1.in ../outputs/4000.case1.out
The total CPU time: 1ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -HS ../inputs/16000.case1.in ../outputs/16000.case1.out
The total CPU time: 3.999ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -HS ../inputs/32000.case1.in ../outputs/32000.case1.out
The total CPU time: 6.999ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -HS ../inputs/1000000.case1.in ../outputs/1000000.case1.out
The total CPU time: 265.959ms
memory: 18668KB

-bash-4.1$ ./NTU_sort -HS ../inputs/4000.case2.in ../outputs/4000.case2.out
The total CPU time: 0.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -HS ../inputs/16000.case2.in ../outputs/16000.case2.out
The total CPU time: 3ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -HS ../inputs/32000.case2.in ../outputs/32000.case2.out
The total CPU time: 6.999ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -HS ../inputs/1000000.case2.in ../outputs/1000000.case2.out
The total CPU time: 249.962ms
memory: 18668KB

-bash-4.1$ ./NTU_sort -HS ../inputs/4000.case3.in ../outputs/4000.case3.out
The total CPU time: 0.999ms
memory: 12500KB
-bash-4.1$ ./NTU_sort -HS ../inputs/16000.case3.in ../outputs/16000.case3.out
The total CPU time: 3ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -HS ../inputs/32000.case3.in ../outputs/32000.case3.out
The total CPU time: 5.999ms
memory: 12648KB
-bash-4.1$ ./NTU_sort -HS ../inputs/1000000.case3.in ../outputs/1000000.case3.out
The total CPU time: 257.961ms
memory: 18668KB

```

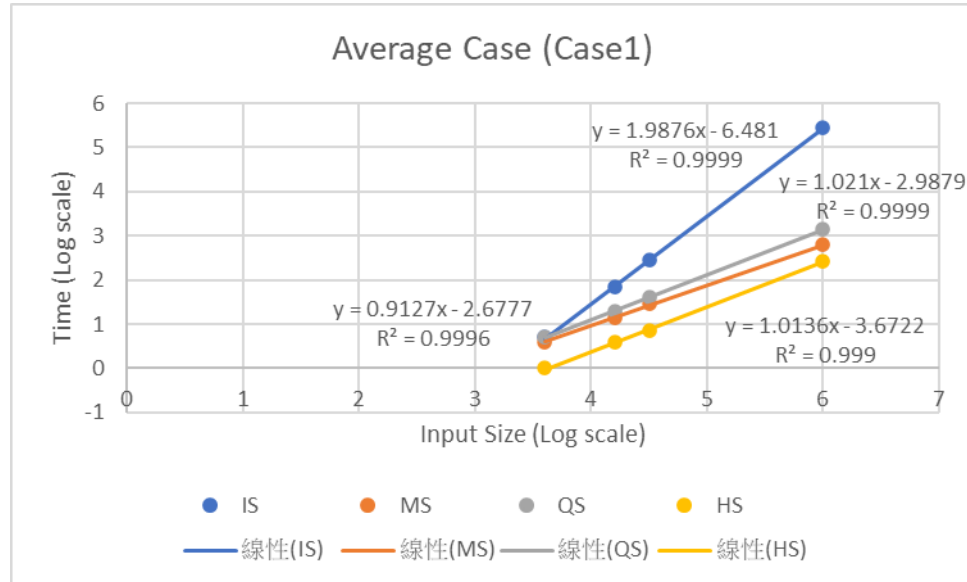
➤ 以下是數據整理的表格：

Input Size	IS		MS		QS		HS	
	CPU time(ms)	Memory(KB)	CPU time(ms)	Memory(KB)	CPU time(ms)	Memory(KB)	CPU time(ms)	Memory(KB)
4000.case2	0	12500	10.999	12500	4.999	12500	0.999	12500
4000.case3	8.999	12500	3	12500	4.999	12500	0.999	12500
4000.case1	4.999	12500	3.999	12500	4.999	12500	1	12500
16000.case2	0	12648	11.998	12648	20.996	12648	3	12648
16000.case3	145.978	12648	11.998	12648	17.997	12648	3	12648
16000.case1	71.989	12648	13.998	12648	19.997	12648	3.999	12648
32000.case2	1	12648	24.996	12836	40.994	12648	6.999	12648
32000.case3	580.911	12648	24.996	12836	35.995	12648	5.999	12648
32000.case1	289.956	12648	28.996	12836	39.994	12648	6.999	12648
1000000.case2	1.999	18668	705.893	22760	1403.79	18668	249.962	18668
1000000.case3	570150	18668	660.899	22760	1373.79	18668	257.961	18668
1000000.case1	284040	18668	617.907	22760	1389.79	18668	265.959	18668

➤ 以下是作圖數據以及作圖結果，其中 0ms 均設為 0.01ms 方便作圖：

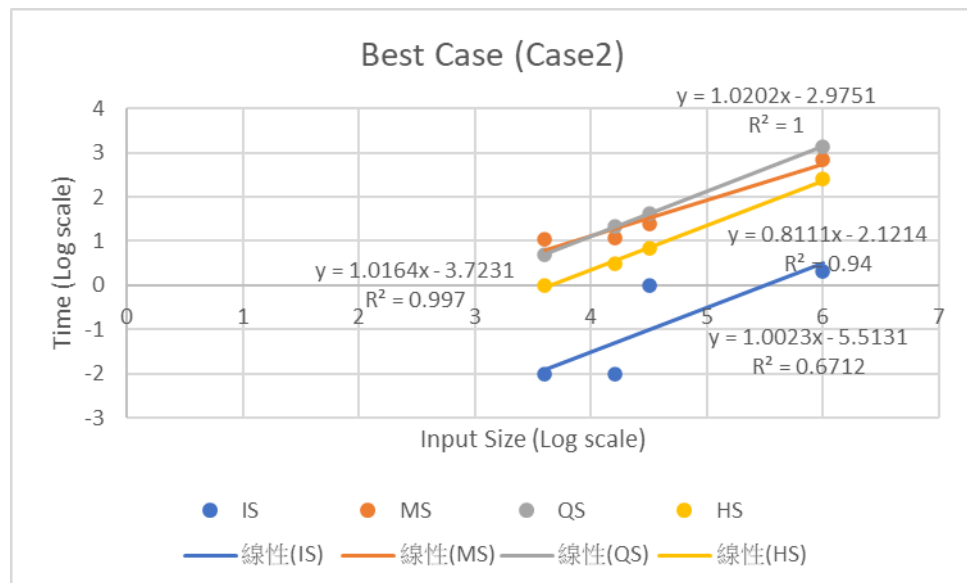
Case1 :

case 1	IS		MS		QS		HS			IS	MS	QS	HS
4000	4.999	12500	3.999	12500	4.999	12500	1	12500	3.60206	0.698883	0.601951	0.698883	0
16000	71.989	12648	13.998	12648	19.997	12648	3.999	12648	4.20412	1.857266	1.146066	1.300965	0.601951
32000	289.956	12648	28.996	12836	39.994	12648	6.999	12648	4.50515	2.462332	1.462338	1.601995	0.845036
1000000	284040	18668	617.907	22760	1389.79	18668	265.959	18668	6	5.45338	2.790923	3.142949	2.424815



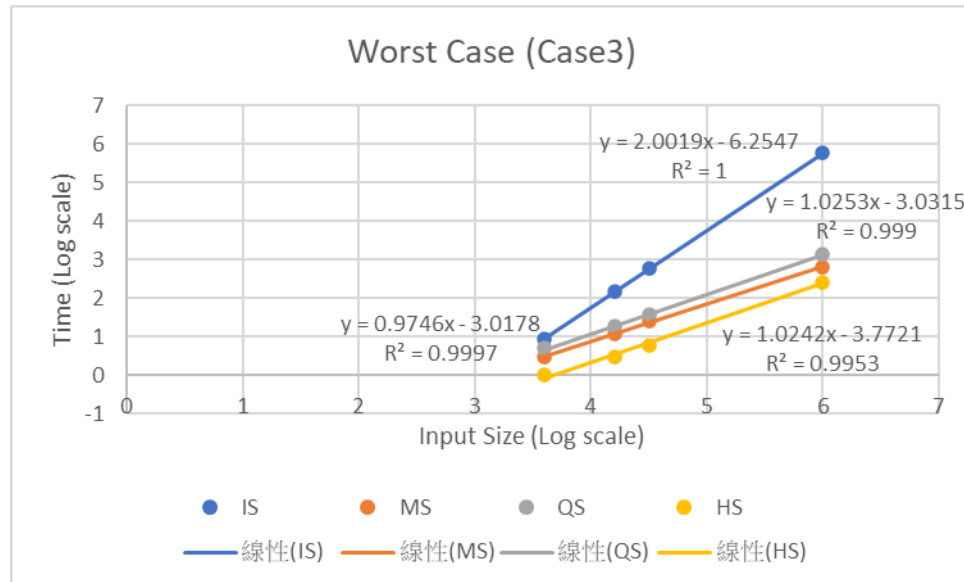
Case2 :

case 2	IS		MS		QS		HS						
4000	0.01	12500	10.999	12500	4.999	12500	0.999	12500	3.60206	-2	1.041353	0.698883	-0.00043
16000	0.01	12648	11.998	12648	20.996	12648	3	12648	4.20412	-2	1.079109	1.322137	0.477121
32000	1	12648	24.996	12836	40.994	12648	6.999	12648	4.50515	0	1.397871	1.61272	0.845036
1000000	1.999	18668	705.893	22760	1403.79	18668	249.962	18668	6	0.300813	2.848739	3.147302	2.397874



Case3 :

case 3	IS			MS			QS			HS						
4000	8.999	12500	3	12500	4.999	12500	0.999	12500	3.60206	0.954194	0.477121	0.698883	-0.00043			
16000	145.978	12648	11.998	12648	17.997	12648	3	12648	4.20412	2.164287	1.079109	1.2552	0.477121			
32000	580.911	12648	24.996	12836	35.995	12648	5.999	12648	4.50515	2.76411	1.397871	1.556242	0.778079			
1000000	570150	18668	660.899	22760	1373.79	18668	257.961	18668	6	5.755989	2.820135	3.13792	2.411554			



- 以下是針對此次作業結果進行的分析與討論：
- (The base of log can be either 2 or 10)
- (Big-O notation is used in the following analyzations though some of them can be expressed as Big-theta notation)

$$\text{if } T(n) = n^2, \text{ then } \log T(n) = 2 \log n$$

$$\text{slope}_{n^2} = \frac{2 \log n}{\log n} = 2$$

$$\text{if } T(n) = n \log n, \text{ then } \log T(n) = \log(n \log n) \approx \log n$$

$$\text{slope}_{n \log n} = \frac{\log(n \log n)}{\log n} = 1 + \frac{\log \log n}{\log n} \approx 1$$

$$\text{if } T(n) = n, \text{ then } \log T(n) = \log n$$

$$\text{slope}_{\log n} = \frac{\log n}{\log n} = 1$$

從以上的計算，我們可以從理論值預期到，Merge Sort、Quick Sort、Heap

Sort 的 case1、case2、case3 (QS 以外) 皆為 $n \log n$ ，因此都會在圖上產生斜率約為 1 的斜直線，其中 Quick Sort 的 Worst Case 應該要是 n^2 ，不過這裡在實做的時候有使用到 random pivot 的技巧，因此觀察到的斜率值仍然是落在 1 附近。

另外在 Insertion Sort 的部分，Average Case 和 Worst Case 是 n^2 符合預期，斜率約為 2，而在 Best Case 的部分，花費時間應為 n ，雖然此處的斜率值和預期相符，不過這裡需要注意因為跑出來實際結果是 0ms，而 0 無法有效地取對數值來作圖，因此這裡假設其值為 0.01ms，實際試過會發現設為 0.1ms 抑或 0.001ms，其回歸線就不會呈現如此接近的斜率，而且 R 值也比較小，可能需要更多 Input Size 較大的數據，才能較準確地描繪出該斜直線。