

2023 Spring CSE222 Homework7 Report

a-) Best, average, and worst-case time complexities analysis of each sorting algorithm.

- Selection Sort: Best, average and worst-case time complexity is $O(n^2)$. This is because it always performs a linear search to find the minimum or maximum element.
- Insertion Sort: Best-case time complexity is $O(n)$ when the array is already sorted. However, average and worst-case time complexity is $O(n^2)$, when the array is reversely sorted or unsorted.
- Bubble Sort: Like Insertion Sort, Bubble Sort's best-case time complexity is $O(n)$ when the array is already sorted. Its average and worst-case time complexity is $O(n^2)$.
- Quick Sort: Quick Sort's best and average case time complexity is $O(n \log n)$, due to divide and conquer strategy. However, in worst-case scenario (when the smallest or largest element is always chosen as pivot), time complexity is $O(n^2)$.

b-) Running time

Best Case:

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
ubuntu@ubuntu-virtual-machine:~/Masaüstü/homework7$ javac *.java
ubuntu@ubuntu-virtual-machine:~/Masaüstü/homework7$ java Main
Original String:      aaaa bbbb cccc
Preprocessed String:  aaaa bbbb cccc

1-MergeSort-->The original (unsorted) map:
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

1-MergeSort-->The sorted map:

1-MergeSort running time: 111667
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

2-SelectionSort-->The original (unsorted) map:
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
```

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2-SelectionSort-->The original (unsorted) map:
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

2-SelectionSort-->The sorted map:

2-SelectionSort running time: 81045
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

3-InsertionSort-->The original (unsorted) map:
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

3-InsertionSort-->The sorted map:
```

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3-InsertionSort-->The sorted map:

3-InsertionSort running time: 54365
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

4-BubbleSort-->The original (unsorted) map:
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

4-BubbleSort-->The sorted map:

4-BubbleSort running time: 45296
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]
```

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4-BubbleSort-->The sorted map:

4-BubbleSort running time: 45296
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

5-QuickSort-->The original (unsorted) map:
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]

5-QuickSort-->The sorted map:

5-QuickSort running time: 58084
Letter: a - Count: 4 - Words: [aaaa, aaaa, aaaa, aaaa]
Letter: b - Count: 4 - Words: [bbbb, bbbb, bbbb, bbbb]
Letter: c - Count: 4 - Words: [cccc, cccc, cccc, cccc]
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```

Average Case:

```
ubuntu@ubuntu-virtual-machine:~/Masaüstü/homework7$ javac *.java
ubuntu@ubuntu-virtual-machine:~/Masaüstü/homework7$ java Main
Original String:      Buzzing bees buzz.
Preprocessed String:  buzzing bees buzz
```

```
1-MergeSort-->The original (unsorted) map:
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: s - Count: 1 - Words: [bees]
```

```
1-MergeSort-->The sorted map:
```

```
1-MergeSort running time: 183088
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
```

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```

```
1-MergeSort running time: 183088
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: s - Count: 1 - Words: [bees]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]

2-SelectionSort-->The original (unsorted) map:
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: s - Count: 1 - Words: [bees]
```

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2-SelectionSort-->The sorted map:

2-SelectionSort running time: 203535
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: s - Count: 1 - Words: [bees]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]

3-InsertionSort-->The original (unsorted) map:
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: s - Count: 1 - Words: [bees]
```

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3-InsertionSort-->The sorted map:

3-InsertionSort running time: 538848
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: s - Count: 1 - Words: [bees]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]

4-BubbleSort-->The original (unsorted) map:
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: s - Count: 1 - Words: [bees]
```

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4-BubbleSort-->The sorted map:

4-BubbleSort running time: 147068
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: s - Count: 1 - Words: [bees]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]

5-QuickSort-->The original (unsorted) map:
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: s - Count: 1 - Words: [bees]
```

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5-QuickSort-->The original (unsorted) map:
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: s - Count: 1 - Words: [bees]

5-QuickSort-->The sorted map:

5-QuickSort running time: 3905097
Letter: i - Count: 1 - Words: [buzzing]
Letter: n - Count: 1 - Words: [buzzing]
Letter: g - Count: 1 - Words: [buzzing]
Letter: s - Count: 1 - Words: [bees]
Letter: u - Count: 2 - Words: [buzzing, buzz]
Letter: e - Count: 2 - Words: [bees, bees]
Letter: b - Count: 3 - Words: [buzzing, bees, buzz]
Letter: z - Count: 4 - Words: [buzzing, buzzing, buzz, buzz]
ubuntu@ubuntu-virtual-machine:~/Masaüstü/homework7$
```

Worst Case:

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
ubuntu@ubuntu-virtual-machine:~/Masaüstü/homework7$ java Main
Original String:      zzzzzzzzzzzz yyyxxxxx www vvv uu tt s r q p o n m l k j
i h g f e d c b a
Preprocessed String:  zzzzzzzzzzzz yyyxxxxx www vvv uu tt s r q p o n m l k j
i h g f e d c b a

1-MergeSort-->The original (unsorted) map:
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
Letter: y - Count: 4 - Words: [yyyxxxxx, yyyxxxxx, yyyxxxxx, yyyxxxxx]
Letter: x - Count: 4 - Words: [yyyxxxxx, yyyxxxxx, yyyxxxxx, yyyxxxxx]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]

Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]

1-MergeSort-->The sorted map:

1-MergeSort running time: 345685
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
```



```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
```

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ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
2-SelectionSort-->The original (unsorted) map:
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
```



```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]

2-SelectionSort-->The sorted map:

2-SelectionSort running time: 634674
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
```

```
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2-SelectionSort-->The sorted map:

2-SelectionSort running time: 634674
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]
Letter: u - Count: 2 - Words: [uu, uu]
```

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: d - Count: 1 - Words: [d]
Letter: a - Count: 1 - Words: [a]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]

3-InsertionSort-->The original (unsorted) map:
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: s - Count: 1 - Words: [s]
```

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]

3-InsertionSort-->The sorted map:
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3-InsertionSort-->The sorted map:

3-InsertionSort running time: 167956
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
```

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Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]

4-BubbleSort-->The original (unsorted) map:
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: a - Count: 1 - Words: [a]
Letter: b - Count: 1 - Words: [b]
Letter: c - Count: 1 - Words: [c]
Letter: d - Count: 1 - Words: [d]
Letter: e - Count: 1 - Words: [e]
Letter: f - Count: 1 - Words: [f]
Letter: g - Count: 1 - Words: [g]
```

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
[...]
```

4-BubbleSort-->The original (unsorted) map:

Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]

Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]

Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]

Letter: w - Count: 3 - Words: [www, www, www]

Letter: v - Count: 3 - Words: [vvv, vvv, vvv]

Letter: u - Count: 2 - Words: [uu, uu]

Letter: t - Count: 2 - Words: [tt, tt]

Letter: s - Count: 1 - Words: [s]

Letter: r - Count: 1 - Words: [r]

Letter: q - Count: 1 - Words: [q]

Letter: p - Count: 1 - Words: [p]

Letter: o - Count: 1 - Words: [o]

Letter: n - Count: 1 - Words: [n]

Letter: m - Count: 1 - Words: [m]

Letter: l - Count: 1 - Words: [l]

Letter: k - Count: 1 - Words: [k]

Letter: j - Count: 1 - Words: [j]

Letter: i - Count: 1 - Words: [i]

Letter: h - Count: 1 - Words: [h]

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
[...]
```

Letter: k - Count: 1 - Words: [k]

Letter: j - Count: 1 - Words: [j]

Letter: i - Count: 1 - Words: [i]

Letter: h - Count: 1 - Words: [h]

Letter: g - Count: 1 - Words: [g]

Letter: f - Count: 1 - Words: [f]

Letter: e - Count: 1 - Words: [e]

Letter: d - Count: 1 - Words: [d]

Letter: c - Count: 1 - Words: [c]

Letter: b - Count: 1 - Words: [b]

Letter: a - Count: 1 - Words: [a]

4-BubbleSort-->The sorted map:

4-BubbleSort running time: 279280

Letter: s - Count: 1 - Words: [s]

Letter: r - Count: 1 - Words: [r]

Letter: q - Count: 1 - Words: [q]

Letter: p - Count: 1 - Words: [p]

Letter: o - Count: 1 - Words: [o]

Letter: n - Count: 1 - Words: [n]

Letter: m - Count: 1 - Words: [m]

Letter: l - Count: 1 - Words: [l]

Letter: k - Count: 1 - Words: [k]

Letter: j - Count: 1 - Words: [j]

Letter: i - Count: 1 - Words: [i]

Letter: h - Count: 1 - Words: [h]

Letter: g - Count: 1 - Words: [g]

Letter: f - Count: 1 - Words: [f]

Letter: e - Count: 1 - Words: [e]

Letter: d - Count: 1 - Words: [d]

Letter: c - Count: 1 - Words: [c]

Letter: b - Count: 1 - Words: [b]

Letter: a - Count: 1 - Words: [a]

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
```

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
5-QuickSort-->The original (unsorted) map:
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
```

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]

5-QuickSort-->The sorted map:

5-QuickSort running time: 400845
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]
```

```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: a - Count: 1 - Words: [a]

5-QuickSort-->The sorted map:

5-QuickSort running time: 400845
Letter: s - Count: 1 - Words: [s]
Letter: r - Count: 1 - Words: [r]
Letter: q - Count: 1 - Words: [q]
Letter: p - Count: 1 - Words: [p]
Letter: o - Count: 1 - Words: [o]
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]
```



```
ubuntu@ubuntu-virtual-machine: ~/Masaüstü/homework7
Letter: n - Count: 1 - Words: [n]
Letter: m - Count: 1 - Words: [m]
Letter: l - Count: 1 - Words: [l]
Letter: k - Count: 1 - Words: [k]
Letter: j - Count: 1 - Words: [j]
Letter: i - Count: 1 - Words: [i]
Letter: h - Count: 1 - Words: [h]
Letter: g - Count: 1 - Words: [g]
Letter: f - Count: 1 - Words: [f]
Letter: e - Count: 1 - Words: [e]
Letter: d - Count: 1 - Words: [d]
Letter: c - Count: 1 - Words: [c]
Letter: b - Count: 1 - Words: [b]
Letter: a - Count: 1 - Words: [a]
Letter: u - Count: 2 - Words: [uu, uu]
Letter: t - Count: 2 - Words: [tt, tt]
Letter: w - Count: 3 - Words: [www, www, www]
Letter: v - Count: 3 - Words: [vvv, vvv, vvv]
Letter: x - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: y - Count: 4 - Words: [yyyyxxxx, yyyyxxxx, yyyyxxxx, yyyyxxxx]
Letter: z - Count: 12 - Words: [zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzz
zzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz, zz
zzzzzzzzzz, zzzzzzzzzzzz, zzzzzzzzzzzz]
ubuntu@ubuntu-virtual-machine:~/Masaüstü/homework7$
```

c-) Comparison of the sorting algorithms:

Selection Sort, Insertion Sort and Bubble Sort have similar time complexities. They perform well on small or nearly sorted lists but are inefficient on large lists. Quick Sort, on the other hand, is generally more efficient on large lists due to its best and average time complexity of $O(n \log n)$. However, Quick Sort can perform poorly if a poor pivot is chosen (worst case scenario). As shown in option b in the project, different values from the theoretical have emerged.

d) Stability of the sorting algorithms:

Stable sorting algorithms maintain the relative order of records with equal keys. In the context of this assignment, it would mean maintaining the order in which elements with the same count were added.

Insertion Sort: Stable. Elements with the same value appear in the same order in the sorted output as they appear in the input.

Bubble Sort: Stable for the same reasons as Insertion Sort.

Selection Sort: Unstable. For example, if the smallest element is not unique, then its first occurrence may be swapped with the last occurrence, thereby changing the relative order.

Quick Sort: Unstable. Due to the partitioning nature of Quick Sort, it's likely to change the relative order of elements with the same value.

The specific parts of the code causing these behaviours are typically where swaps are made. In the unstable algorithms, swapping doesn't take into account the original order of elements with equal keys.