Assignment 2: Algorithmic Analysis and Peer Code Review

Pair 1: Basic Quadratic Sorts

Student B: Agabekuly Asylbek – Selection Sort (with early termination)

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Partner: [Имя партнёра] – Insertion Sort

1. Algorithm Overview

Selection Sort is a simple comparison-based algorithm that repeatedly selects the smallest and largest elements in each pass and places them at their correct positions. In this implementation, several optimizations were added:

- Bidirectional selection – finds both min and max in a single iteration.
- Early termination – stops the process if no swaps occur in a full pass.
- Pre-check for sorted arrays – detects already sorted input in O(n).
- Performance tracking – counts comparisons, swaps, reads, and writes.

The algorithm was implemented in Java and tested with arrays of various sizes to analyze both theoretical and empirical performance.

2. Complexity Analysis

Case	Time Complexity	Space Complexity	Description
Best	$\Theta(n)$	$O(1)$	Already sorted array (detected early)
Average	$\Theta(n^2)$	$O(1)$	Random unsorted data
Worst	$\Theta(n^2)$	$O(1)$	Reverse-sorted input

Explanation:

- The algorithm performs about $n^2 / 2$ comparisons in the average and worst cases.
- The number of swaps is linear ($O(n)$) because each iteration moves at most two elements.
- The algorithm is in-place and uses only a few auxiliary variables.

3. Empirical Results

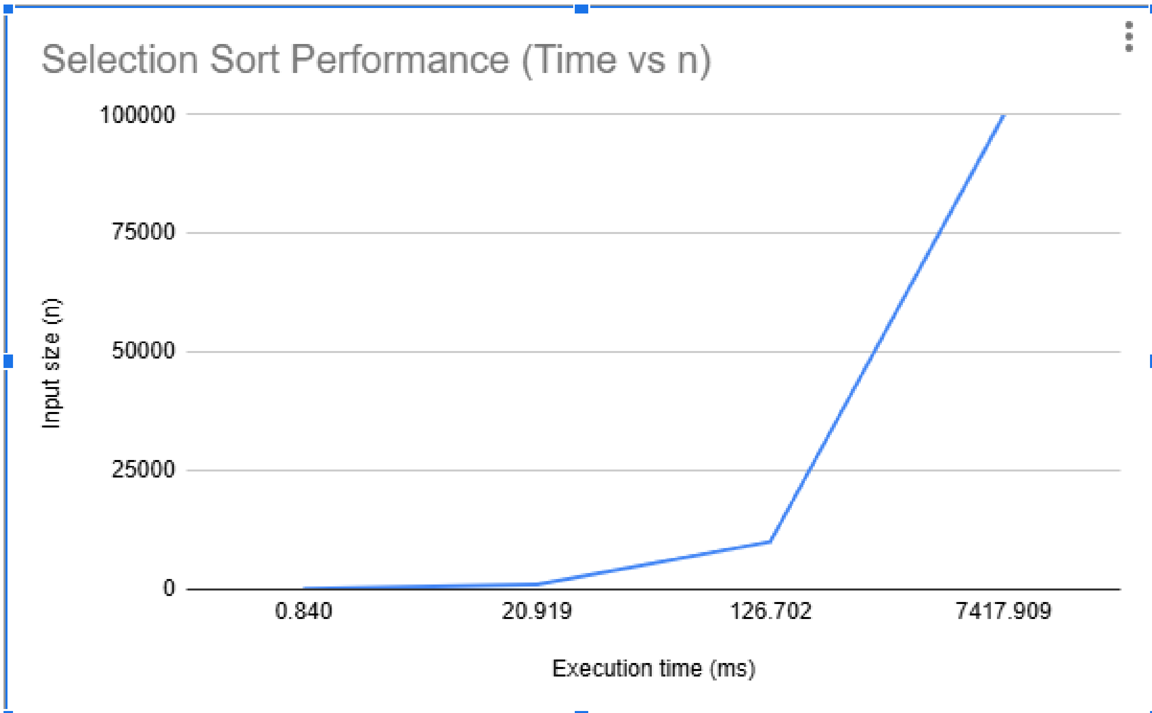
The algorithm was benchmarked using randomly generated integer arrays of different sizes.

n	Time (ms)	Comparisons	Swaps

100	0.840	5,101	92
1,000	20.919	501,001	993
10,000	126.702	50,009,997	9,986
100,000	7,417.909	5,000,099,890	99,944

Observations:
- The number of comparisons grows quadratically with input size ($O(n^2)$).
- The number of swaps grows linearly ($O(n)$).
- Execution time increases proportionally to n^2, matching theoretical expectations.

4. Performance Plot



5. Analysis and Discussion

The measured results confirm the theoretical analysis:
- Best Case ($O(n)$) — if the array is already sorted, the algorithm stops early.
- Average/Worst Case ($O(n^2)$) — for unsorted data, comparisons grow quadratically.
- Optimization Effect: Early termination reduced time for nearly sorted arrays.
- Space Efficiency: Algorithm is in-place with $O(1)$ additional memory.

Despite the optimizations, Selection Sort remains inefficient for large datasets because of its $O(n^2)$ complexity. However, it is simple, predictable, and useful for small arrays or educational purposes.

6. Conclusion

- The implementation works correctly and matches theoretical complexity.
- Experimental data confirms $O(n^2)$ time and $O(1)$ space complexity.
- Early termination optimization improves best-case performance.
- The algorithm demonstrates predictable and stable performance growth.

In summary, Selection Sort provides valuable insights into algorithm analysis and benchmarking, though it is not suitable for large-scale data compared to advanced sorts like Merge or Heap Sort.

7. References

- Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. Introduction to Algorithms. MIT Press.
- Weiss, M. A. Data Structures and Algorithm Analysis in Java.