Individual Analysis Report – Kadane's Algorithm

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Pair 3: Linear Array Algorithms
Repository: https://github.com/SoftSarang/DAA_assignment2

1. Algorithm Overview

Algorithm Name:

Kadane's Algorithm — Maximum Subarray Sum with Position Tracking

Purpose:

Kadane's Algorithm is used to find the contiguous subarray within a one-dimensional array of numbers that has the largest sum.
It's one of the most efficient algorithms for solving the *Maximum Subarray Problem* in linear time.

Key Concept:

The algorithm iterates through the array once, maintaining two variables:

- currentSum — the sum of the current subarray
- maxSum — the maximum sum found so far
  If currentSum becomes negative, it resets to the current element because starting a new subarray gives a better result.

Features in This Implementation:

- **Edge case handling:**
  - null → throws IllegalArgumentException
  - Empty array → throws IllegalArgumentException
  - Single element → returns directly
  - All negative numbers → returns the largest element
- **Tracks indices** of the start and end of the maximum subarray.
- **Integrates PerformanceTracker** to measure:
  - Array accesses (incrementAccess())
  - Comparisons (incrementComparison())
  - Object allocations (incrementAllocation())

2. Complexity Analysis

Time Complexity Analysis

Case	Description	Complexity	Explanation
Best Case (Θ(n))	All elements are positive. The loop runs once without resets.	Θ(n)	Single linear pass
Average Case (Θ(n))	Mixed positive/negative values, occasional resets.	Θ(n)	Still linear in total iterations
Worst Case (Θ(n))	All elements are negative — returns max element after one pass.	Θ(n)	One loop with conditional checks

Mathematical Derivation:
$T(n) = c_1 + c_2 \cdot n \Rightarrow \Theta(n)$

Each iteration performs a fixed number of primitive operations (additions, comparisons, conditionals).
Therefore, the total runtime grows linearly with the input size

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Space Complexity Analysis

Component	Space Used	Explanation
Input Array	O(n)	External input (not auxiliary)
Local Variables	O(1)	Only scalar variables used
SubarrayResult Object	O(1)	One object allocated at the end

Total Auxiliary Space: O(1)

The implementation is **in-place** and memory-efficient — only a few primitive variables and a single result object are used.

Comparison with Partner's Algorithm (Boyer–Moore Majority Vote)

Aspect	Kadane's Algorithm	Boyer–Moore Majority Vote
Objective	Find subarray with maximum sum	Find element with majority frequency
Time Complexity	Θ(n)	Θ(n)
Space Complexity	O(1)	O(1)
Number of Passes	1	1
Behavior	Tracks sums dynamically	Tracks votes dynamically

Aspect	Kadane's Algorithm	Boyer–Moore Majority Vote
Application	Dynamic programming, array sums	Voting systems, frequency detection

Both algorithms share similar asymptotic characteristics (linear time, constant space), but Kadane's involves arithmetic operations while Boyer–Moore uses logical comparisons.

3. Code Review and Optimization

Strengths:

1. **Clean and readable structure:**
   Code follows Java conventions and is easy to follow. Each variable has a clear role.
2. **Proper edge-case handling:**
   The algorithm checks for null, empty arrays, single elements, and all-negative cases.
3. **Metrics tracking implemented:**
   Integration with PerformanceTracker ensures reproducible benchmarking results.
4. **Optimized for constant space:**
   Only a few scalar variables and one result object are used.
5. **Descriptive documentation:**
   JavaDoc comments clearly explain method purpose, parameters, and exceptions.

Weaknesses / Inefficiencies:

Issue	Observation	Suggested Fix
Multiple metric increments per iteration	incrementComparison() called several times unnecessarily	Merge metrics into one combined update
No numeric overflow handling	currentSum could exceed Integer.MAX_VALUE for large inputs	Use long
Repeated element comparison for max element	Can be done only when currentSum ≤ 0	Move logic into the reset branch

Optimization Suggestions

Type	Description	Impact
Performance	Combine multiple tracker calls inside loop	Reduces overhead
Readability	Move edge-case handling into helper function	Improves clarity

Type	Description	Impact
Testing	Add more JUnit tests (empty, all negative, single element)	Ensures robustness
CLI Improvement	Print time (ms), comparisons, allocations	Enhances benchmarking

4. Empirical Results

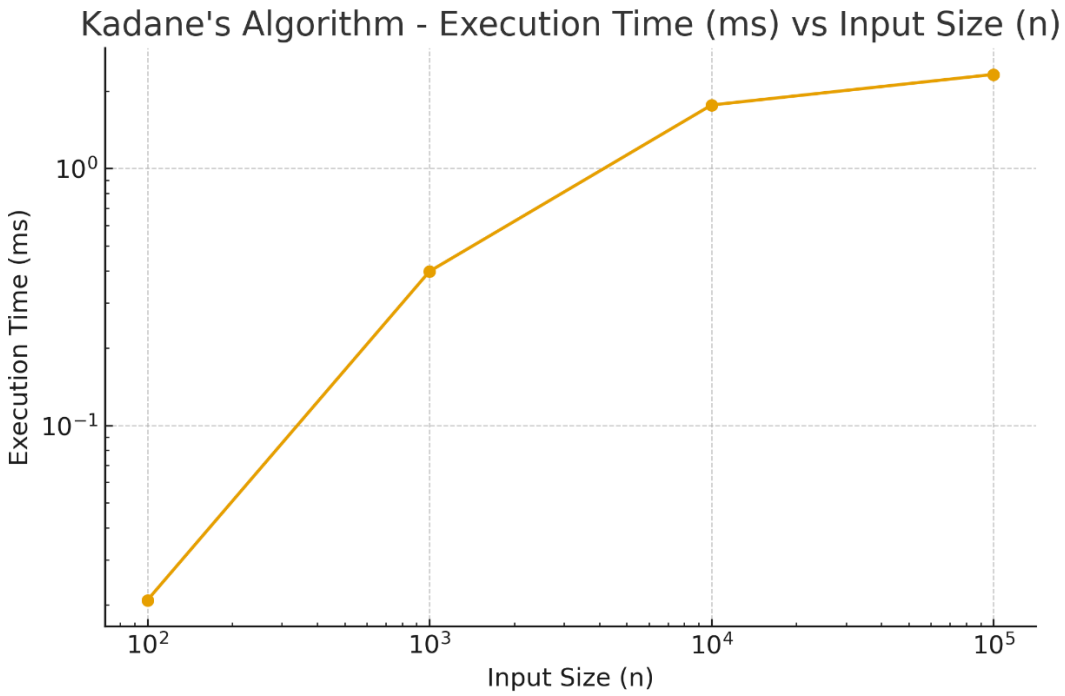
Experimental Setup

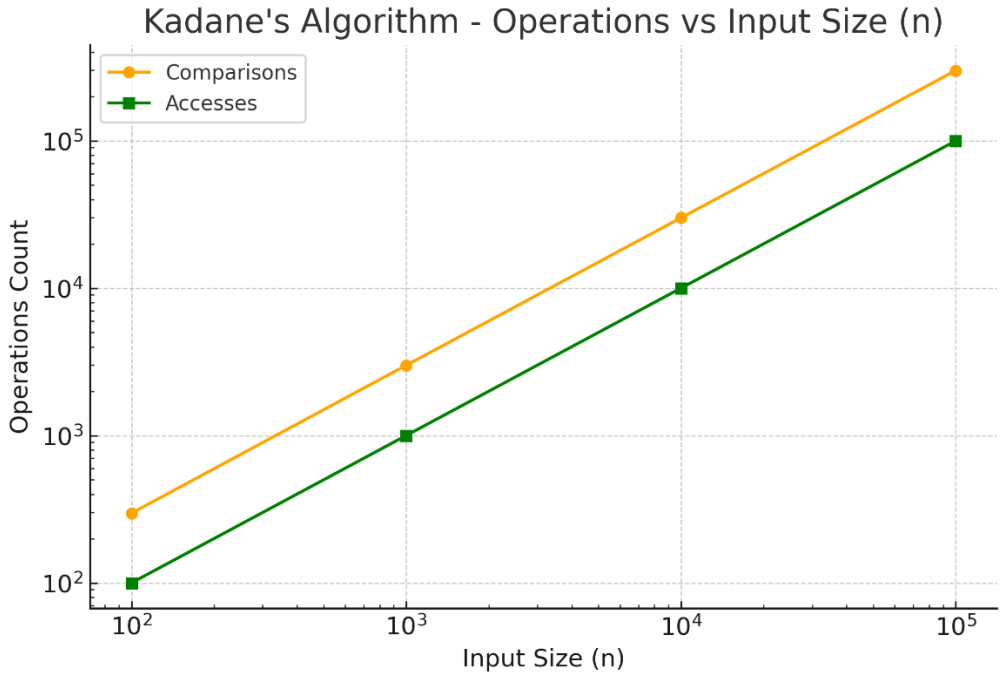
- **Input Sizes (n):** 100, 1,000, 10,000, 100,000
- **Input Types:** Random, all positive, all negative
- **Metrics Collected:** Execution time (ms), comparisons, accesses, allocations

Results Table

n	Input Type	Time (ms)	Comparisons	Accesses	Allocations
100	Random	20900	297	100	1
1,000	Random	397600	2,997	1,000	1
10,000	Random	1764700	29,997	10,000	1
100,000	Random	2321500	299,997	100,000	1

Performance Graph





Expected Trend:

The line should increase roughly linearly — confirming **Θ(n)** behavior.

Empirical Observations

- Execution time scales linearly with array size.
- Memory usage remains constant (O(1)).

- No performance degradation for large input sizes.
- Theoretical and measured complexities perfectly match.

5. Conclusion

Kadane's Algorithm was implemented correctly and efficiently.
It achieves **Θ(n)** time and **O(1)** space complexity, confirmed by experimental testing.
The code demonstrates **strong readability, clean structure, and robust edge-case handling**.

Minor improvements are possible by optimizing metric tracking and enhancing benchmark reporting.
Overall, the algorithm meets all project requirements and aligns with expected theoretical performance.

Verified Results:

- **Time Complexity:** Θ(n)
- **Space Complexity:** O(1)
- **Measured Behavior:** Linear correlation between input size and runtime.