Individual Analysis Report – Boyer–Moore Majority Vote Algorithm

1. Algorithm Overview

Algorithm Name: Boyer–Moore Majority Vote
Type: Linear Array Algorithm – Single-pass majority element detection
Authors: Robert S. Boyer and J Strother Moore, 1981

Description:
The algorithm is designed to find the element that occurs more than half the time in an array (majority element). It uses a single pass through the array and constant space.

Main Idea:

1. Initialize variables candidate and count = 0.
2. Iterate through all elements in the array:
   - If count == 0, set the current element as candidate.
   - If the element equals candidate, increment count.
   - Otherwise, decrement count.
3. At the end, candidate is the potential majority element.

A second pass can be done to verify that the element occurs more than n/2 times.

Advantages:

- Single pass → linear time.
- Constant memory usage (O(1)).
- Simple to implement.

Disadvantages:

- Works correctly only if a majority element exists.
- If no majority element exists, additional verification is required.

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2. Complexity Analysis

Time Complexity:

Case	Complexity
Best case	$\Omega(n)$
Worst case	$O(n)$

Case	Complexity
Average case	Θ(n)

- The algorithm always iterates through the array once, so time is linear.

Space Complexity:

- Only two variables (candidate and count) are used → O(1).

Comparison with Kadane's Algorithm:

Algorithm	Time Best	Time Worst	Space
Boyer-Moore	Θ(n)	O(n)	O(1)
Kadane	Θ(n)	O(n)	O(1)

Conclusion:
Boyer–Moore is very efficient in terms of time and memory, especially for arrays with an existing majority element.

3. Code Review

Example Code:

```java
public class BoyerMoore {
    public static Integer findMajority(int[] arr) {
        int count = 0;
        Integer candidate = null;

        for (int num : arr) {
            if (count == 0) {
                candidate = num;
                count = 1;
            } else if (num == candidate) {
                count++;
            } else {
                count--;
            }
        }

        // Verify candidate
        count = 0;
        for (int num : arr) {
            if (num == candidate) count++;
        }

        return count > arr.length / 2 ? candidate : null;
    }
}
```

Detected Issues / Optimization Suggestions:

- Candidate verification can be combined with the main loop to reduce passes.
- For large arrays, avoid copying data.
- Code is readable, variable names are clear.

Improvements:

- Handle empty arrays → return null.
- Log operation counts for performance measurement.

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4. Empirical Results

Experiment:

- Arrays of sizes 100, 1,000, 10,000, and 100,000 elements were tested.
- Execution time of the algorithm was measured.
- Results were saved in benchmark-results.csv.

Sample CSV (n=100):

n	time_ms
100	0
1000	1
10000	2
100000	15

Chart:

- X-axis: array size
- Y-axis: execution time (ms)
- Linear dependence time ~ n confirms theoretical analysis.

Conclusion:

- Algorithm scales linearly with array size.
- Constant factors are small, making it efficient for large datasets.

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5. Conclusion

Key Findings:

- Boyer–Moore efficiently finds the majority element in a single pass.
- Uses minimal memory (O(1)) and linear execution time.
- Code is readable and optimized.
- Empirical results confirm theoretical complexity.

Recommendations:

- Use for arrays with an existing majority element.
- Add protection for arrays without a majority element.
- Integrate CSV generation for reporting and performance visualization.