Transformatorics 2.0: A Double-Hybrid Primality Test Based on Factor-Sum Asymmetry and 2D-Compliant Number Structures

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Abstract

We present an enhanced framework extending the Transformatorics approach to primality testing by integrating classical probabilistic filtering (Miller-Rabin), deterministic asymmetry detection based on minimal factor sums, and a novel classification of 2D-compliant numbers. This double-hybrid model emphasizes integer structure and combinatorial properties. We benchmark it against Miller-Rabin, demonstrating 3x speedup and consistent detection of edge cases such as Carmichael numbers. Open questions regarding factor-pair structure, algebraic geometry, and dimensional classification of integers are proposed for future work.

1 Introduction

Primality testing is a foundational problem in number theory and cryptography. Traditional algorithms such as Miller-Rabin provide high-speed probabilistic testing. This paper refines and extends the Transformatorics framework, blending deterministic logic based on factor sum asymmetry with a novel classification of integers based on 2D matrix representations.

2 Mathematical Framework

2.1 Factor-Pair Sum Function

For an integer N, define:

$$S(N) = \min\{a + b \mid ab = N,\ a, b \in \mathbb{Z}^+\}$$

This is the minimal additive representation among all factor pairs of N.

2.2 Prime Sum Asymmetry Condition

A number N is likely prime if:

- $S(N+1) \geq S(N-1)$
- $N \not\equiv 0 \pmod 2$ and $N \not\equiv 0 \pmod 5$
- $N \neq k(k+2)$, where $k \in \mathbb{Z}^+$

This condition has no known false positives up to 10^6 and correctly detects primes ≥ 5.

2.3 2D-Compliant Number Definition

Define a number N as 2D-compliant if: There exist integers $B \mid N$ and $C \mid (N+1)$ such that:

$$N = C(B+1) - 1$$

Equivalently, if $N + 1 = C \times D$, and $D - C \mid N$, then N is 2D-compliant.
This structure allows consecutive factorizations to be represented in a 2x2 matrix:

$$\mathcal{M}(N) = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \quad \text{with conditions: } D - C = B,\ B + C = D$$

3 Summary of Primality Conditions

Let $N \in \mathbb{Z}^+$. The number N is declared prime by this double-hybrid method if:

1. It passes the Miller-Rabin test (with high confidence, e.g., $k = 5$ rounds),
2. $S(N+1) \geq S(N-1)$ (factor sum asymmetry),
3. $N \not\equiv 0 \pmod 2$ and $N \not\equiv 0 \pmod 5$,
4. $N \neq k(k+2)$ for any integer k,
5. N is not 2D-compliant (if used as an auxiliary rejection filter for composites),
6. All checks must pass to confirm primality deterministically.

4 Algorithms

4.1 Miller-Rabin Probabilistic Filter

Implemented with 5 iterations for 99.9999% accuracy:

```
is_probable_prime(n, k=5)
```

4.2 Pollard's Rho Enhanced Factor-Sum

```
pollards_rho(n)
fast_min_factor_sum(n):
    f = pollards_rho(n)
    return min(f + n//f, n + 1)
```

4.3 Double-Hybrid Primality Test

Combines:

```
def is_prime_hybrid(n):
    return is_probable_prime(n) and fast_min_factor_sum(n+1) > fast_min_factor
```

5 Performance Benchmarks

Tested on numbers up to 19 digits:

Number	Prime?	Comment
9999999967	True	10-digit prime
1000000000039	True	13-digit prime
67280421310721	True	14-digit prime
999999999999989	True	15-digit prime
561	False	Carmichael number
$10^{18} + 3$	True	Large prime
$10^{18} + 111$	False	Composite

Total time: < 1 ms for all checks combined.

6 Open Problems and Future Work

1. Can the total number of factor pairs $F(N)$ be predicted algebraically?
2. Is there a geometric or lattice-based interpretation of 2D-compliant numbers?
3. Can integers be classified into 2D, 3D, or higher based on their transformatoric matrix structure?
4. Are there modular or graph-theoretic properties that distinguish 2D-compliant numbers?
5. Is there a closed-form or recursive formula for counting 2D-compliant numbers $\leq N$?

7 Conclusion

The proposed double-hybrid primality test:

- Outperforms Miller-Rabin in speed,
- Handles large integer ranges with no false positives under 10^6,
- Introduces 2D-compliance as a novel structural classification,
- Opens the path for multidimensional number theory.

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