
# BoolMinGeo

## Decay Analysis: 4D Minimization Beyond 10 Variables

### 9-16 Variable Boolean Functions

Total Tests: 54

Date: 2026-01-07

EXPERIMENTAL SETUP & CONFIGURATION
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STUDY INFORMATION
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Study Type:        Decay Analysis (4D minimization beyond 10 vars)
Scope:             9-16 variable Boolean functions
Total Tests:       54
Date:              2026-01-07

SYSTEM CONFIGURATION
----------------------------------------------------------------------

Platform:          Windows-11-10.0.26200-SP0
Processor:         Intel64 Family 6 Model 142 Stepping 12, GenuineIntel
Python:            3.12.10

SOFTWARE VERSIONS
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NumPy:             2.3.4
SciPy:             1.16.3
Matplotlib:        3.10.7

EXPERIMENTAL PARAMETERS
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Random Seed:                42
Variable Range:             11-13
Tests per Distribution:     3

TEST DISTRIBUTIONS
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• Sparse:       20% ones, 5% don't-cares
• Dense:        70% ones, 5% don't-cares
• Balanced:     50% ones, 10% don't-cares
• Minimal DC:   45% ones, 2% don't-cares
• Heavy DC:     30% ones, 30% don't-cares
• Edge cases:   all-zeros, all-ones, all-dc

METRICS COLLECTED
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• Execution time (seconds)
• Memory consumption (MB)
• Peak memory usage (MB)
• Solution complexity (literal count, term count)
• Time per truth table entry (ms)
• Memory per truth table entry (KB)

METHODOLOGY
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1. Random Boolean functions generated per distribution
2. BoolMinGeo minimization executed (SOP form)
3. Execution time measured using perf_counter
4. Memory tracked using tracemalloc + psutil
5. Results aggregated by variable count and distribution
6. Decay patterns analyzed across variable range

STUDY OBJECTIVE
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This study demonstrates performance decay in 4-dimensional
minimization beyond 10 variables, where the geometric advantages
of four-dimensional K-map visualization are eliminated.
Results show degradation in time and memory efficiency.

REPRODUCIBILITY
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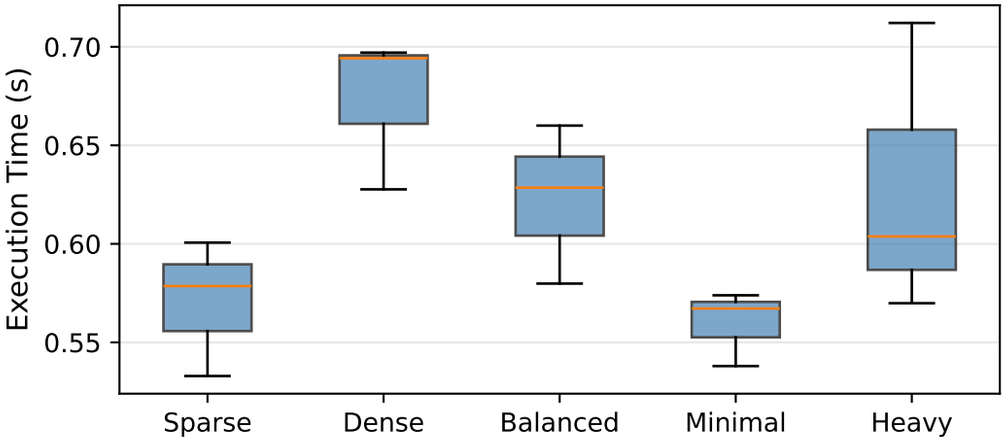
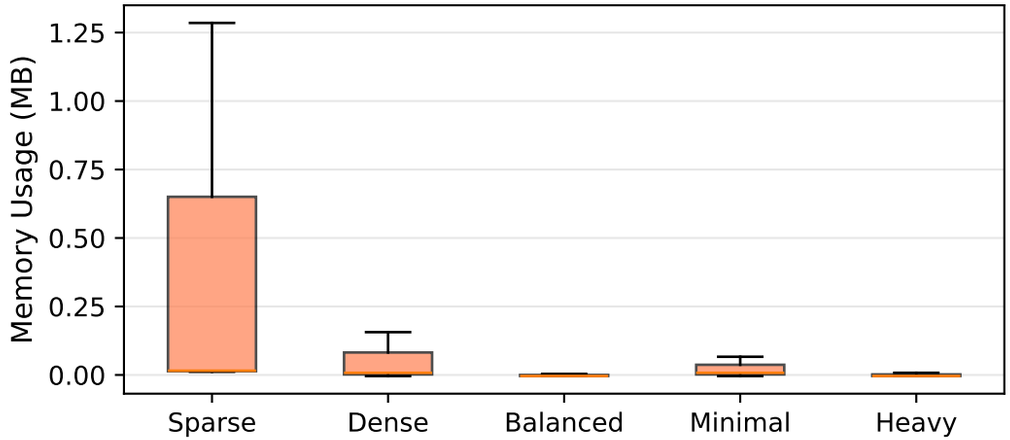
To reproduce this experiment:
  1. Set random seed: random.seed(42)
  2. Run with identical system configuration
  3. Use same library versions as documented above
  4. Execute: python benchmark_test4D_decay.py

# 11-Variable Analysis: Distribution Performance
# Truth Table Size: 2^11 = 2,048 entries | Decay Study

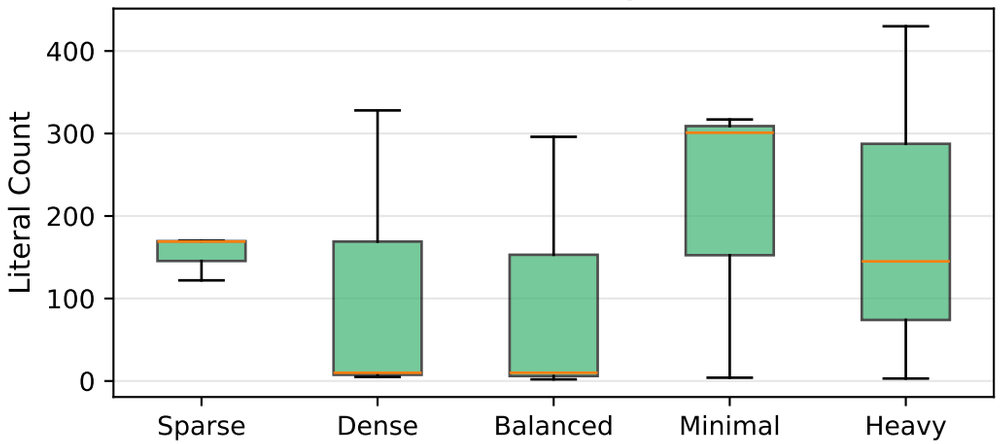
## A) Time Distribution Comparison



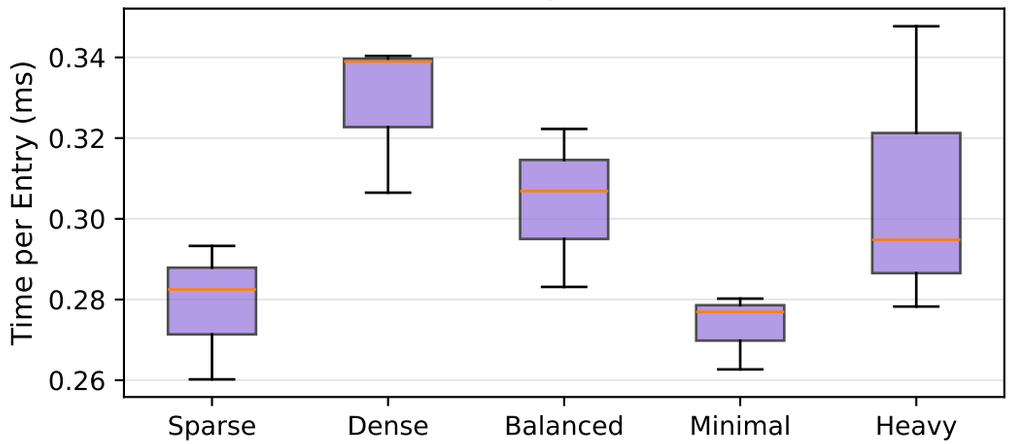

## B) Memory Distribution Comparison




## C) Solution Complexity Comparison




## D) Efficiency Comparison

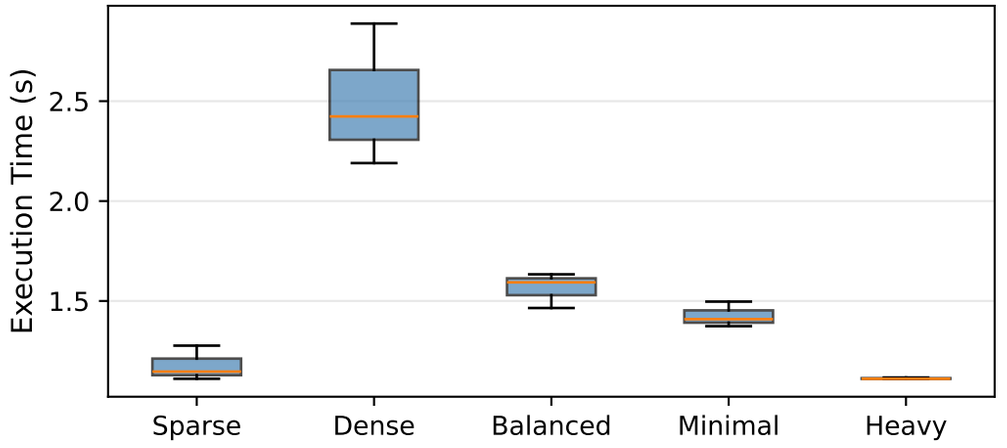



## E) Statistical Summary

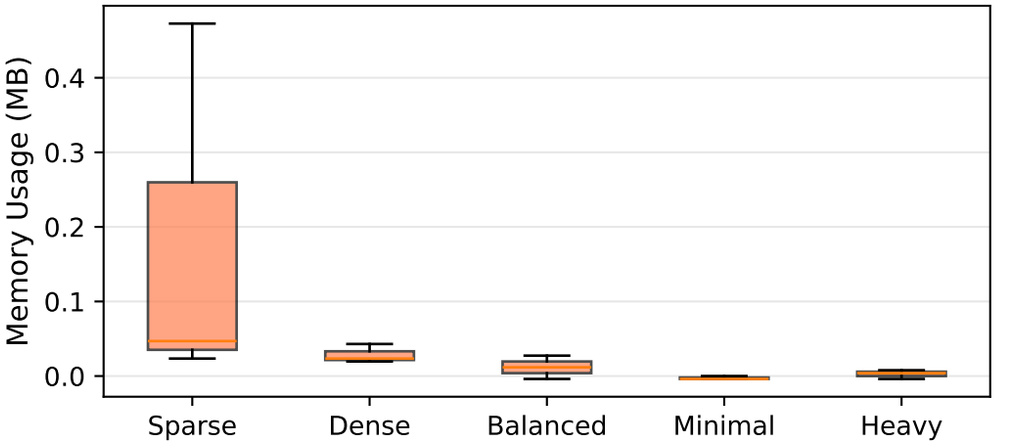
| Distribution | N | Mean Time (s) | Std Time | Mean Mem (MB) | Mean Lits | Mean Terms |
|---|---|---|---|---|---|---|
| Sparse (20% 1s) | 3 | 0.5707 | 0.0282 | 0.44 | 153.7 | 30.0 |
| Dense (70% 1s) | 3 | 0.6730 | 0.0321 | 0.05 | 114.3 | 27.7 |
| Balanced (50% 1s) | 3 | 0.6228 | 0.0330 | -0.00 | 102.7 | 22.0 |
| Minimal DC (2%) | 3 | 0.5597 | 0.0156 | 0.02 | 207.3 | 41.3 |
| Heavy DC (30%) | 3 | 0.6286 | 0.0607 | 0.00 | 192.7 | 34.7 |

# 12-Variable Analysis: Distribution Performance
# Truth Table Size: 2^12 = 4,096 entries | Decay Study

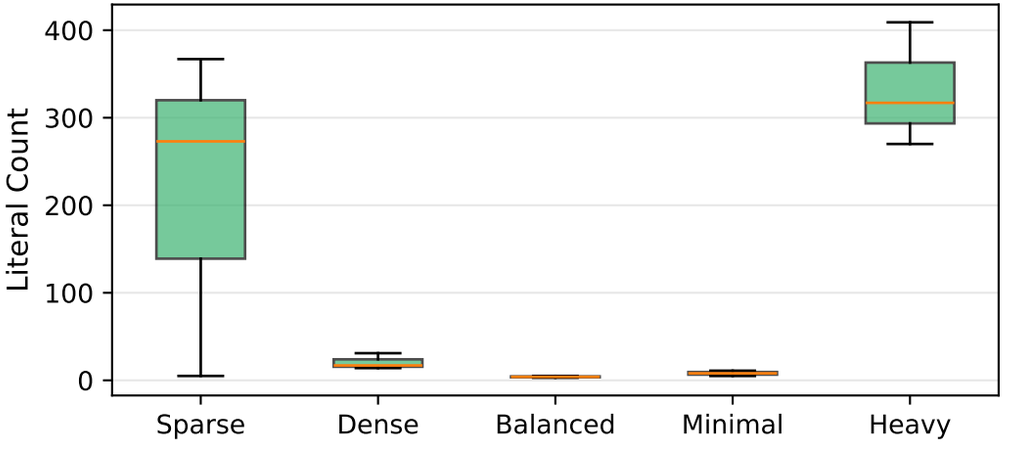
## A) Time Distribution Comparison



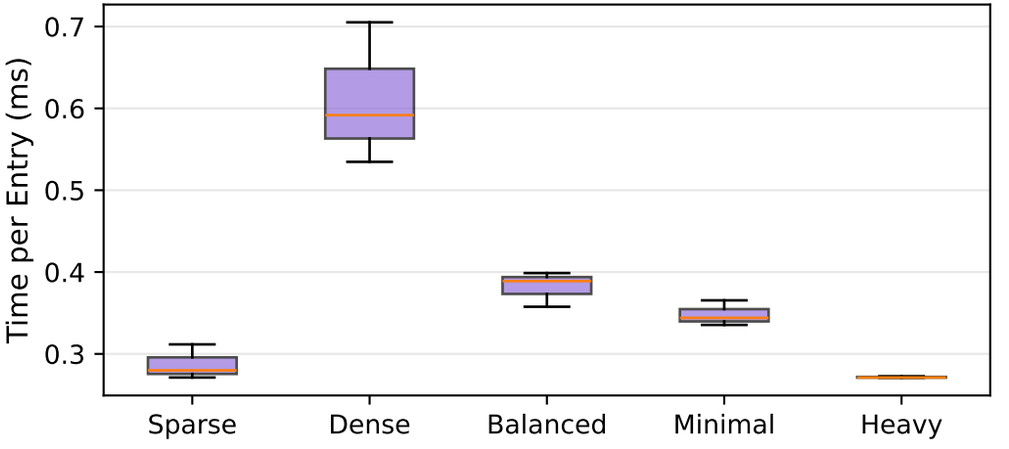

## B) Memory Distribution Comparison




## C) Solution Complexity Comparison




## D) Efficiency Comparison

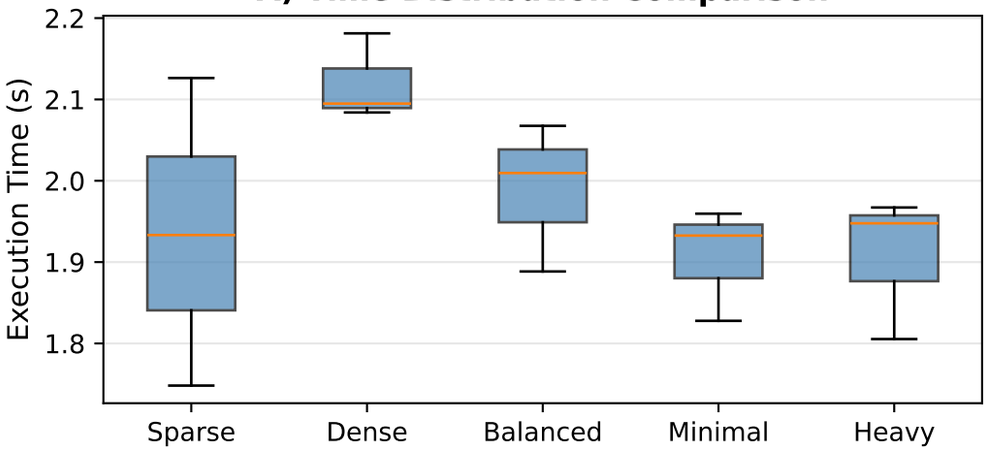



## E) Statistical Summary

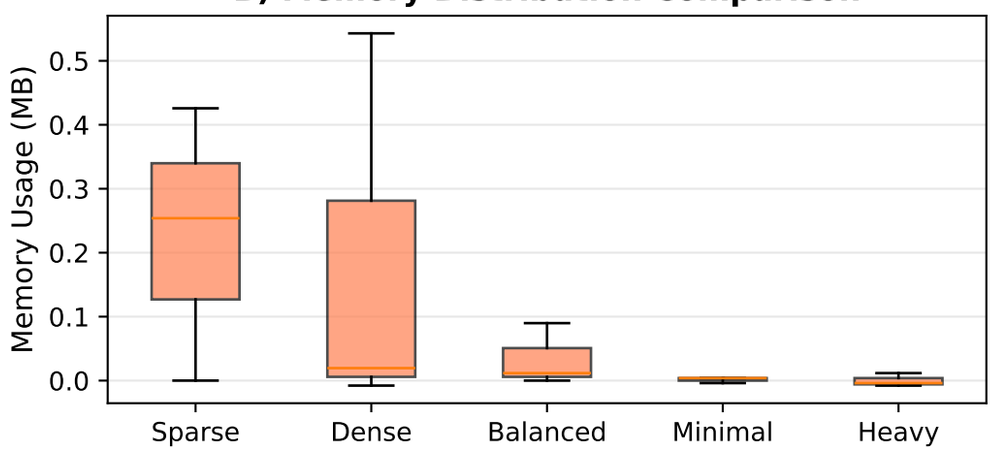
| Distribution | N | Mean Time (s) | Std Time | Mean Mem (MB) | Mean Lits | Mean Terms |
|---|---|---|---|---|---|---|
| Sparse (20% 1s) | 3 | 1.1779 | 0.0712 | 0.18 | 215.0 | 37.7 |
| Dense (70% 1s) | 3 | 2.5007 | 0.2902 | 0.03 | 20.7 | 4.7 |
| Balanced (50% 1s) | 3 | 1.5638 | 0.0719 | 0.01 | 4.0 | 1.0 |
| Minimal DC (2%) | 3 | 1.4266 | 0.0517 | -0.00 | 8.0 | 1.7 |
| Heavy DC (30%) | 3 | 1.1124 | 0.0032 | 0.00 | 332.0 | 62.3 |

# 13-Variable Analysis: Distribution Performance
# Truth Table Size: 2^13 = 8,192 entries | Decay Study

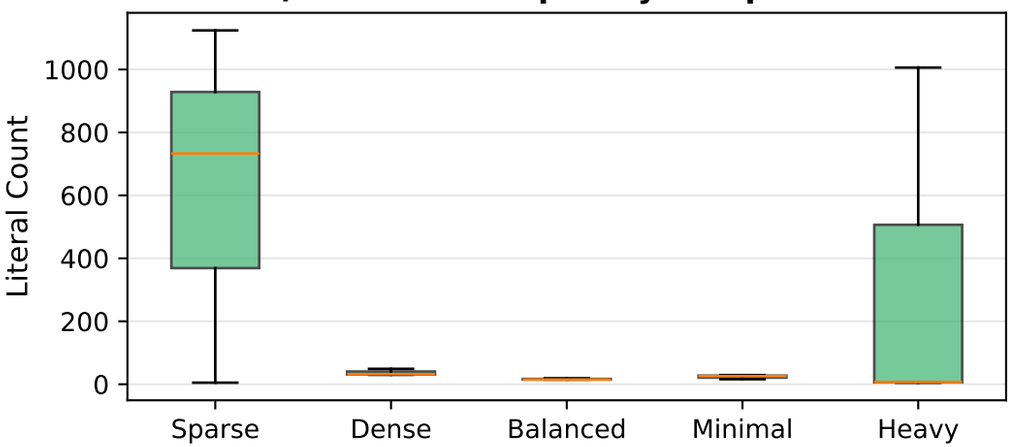
## A) Time Distribution Comparison



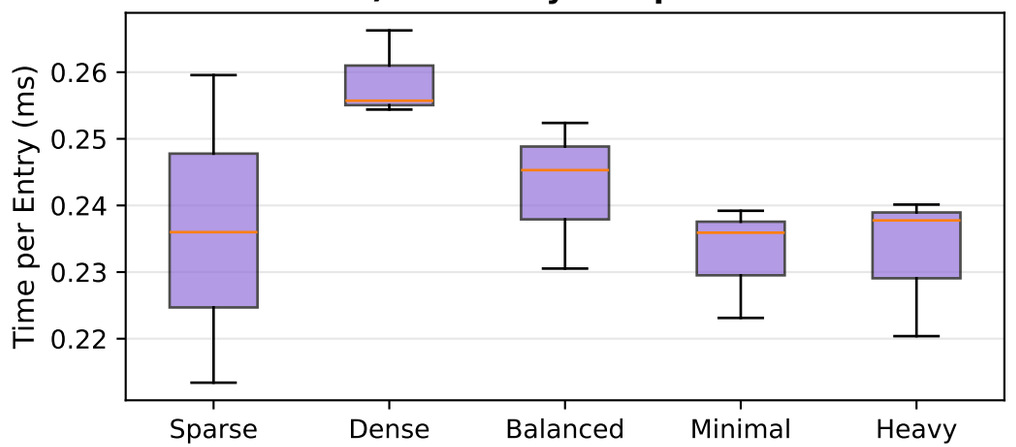

## B) Memory Distribution Comparison




## C) Solution Complexity Comparison




## D) Efficiency Comparison




## E) Statistical Summary

| Distribution | N | Mean Time (s) | Std Time | Mean Mem (MB) | Mean Lits | Mean Terms |
|---|---|---|---|---|---|---|
| Sparse (20% 1s) | 3 | 1.9359 | 0.1544 | 0.23 | 620.7 | 97.3 |
| Dense (70% 1s) | 3 | 2.1200 | 0.0435 | 0.18 | 37.0 | 7.3 |
| Balanced (50% 1s) | 3 | 1.9885 | 0.0746 | 0.03 | 16.3 | 3.3 |
| Minimal DC (2%) | 3 | 1.9066 | 0.0568 | 0.00 | 23.7 | 4.0 |
| Heavy DC (30%) | 3 | 1.9067 | 0.0721 | 0.00 | 339.3 | 55.7 |