



# 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

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

NumPy: 2.3.4  
SciPy: 1.16.3  
Matplotlib: 3.10.7

### EXPERIMENTAL PARAMETERS

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

### TEST DISTRIBUTIONS

- 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

- 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

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

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

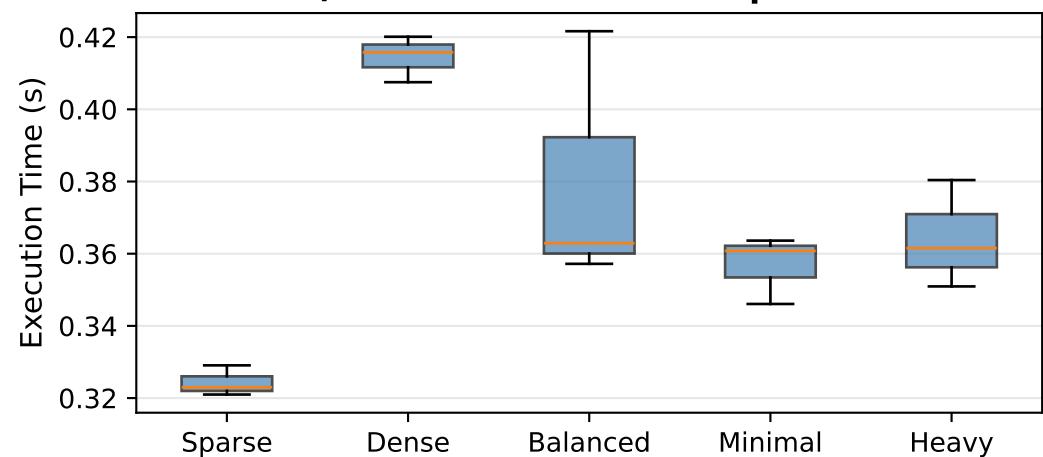
To reproduce this experiment:

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`

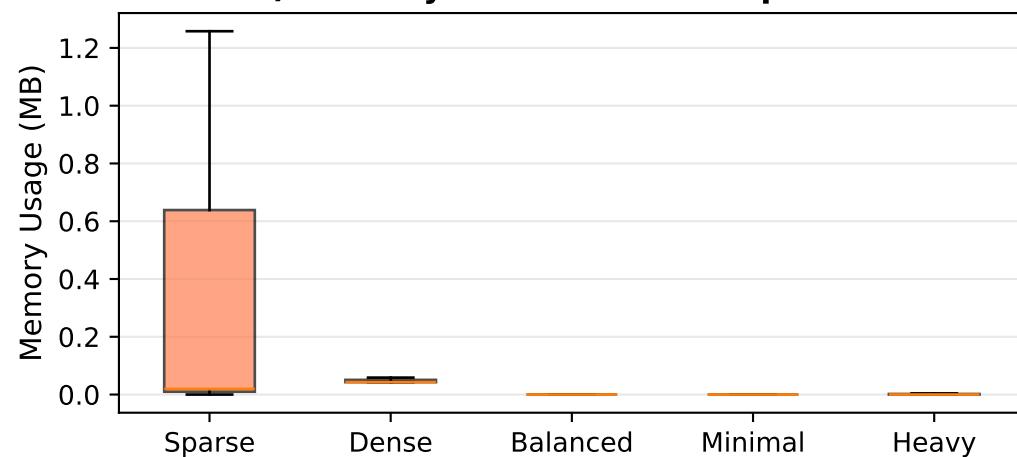
# 11-Variable Analysis: Distribution Performance

Truth Table Size:  $2^{11} = 2,048$  entries | Decay Study

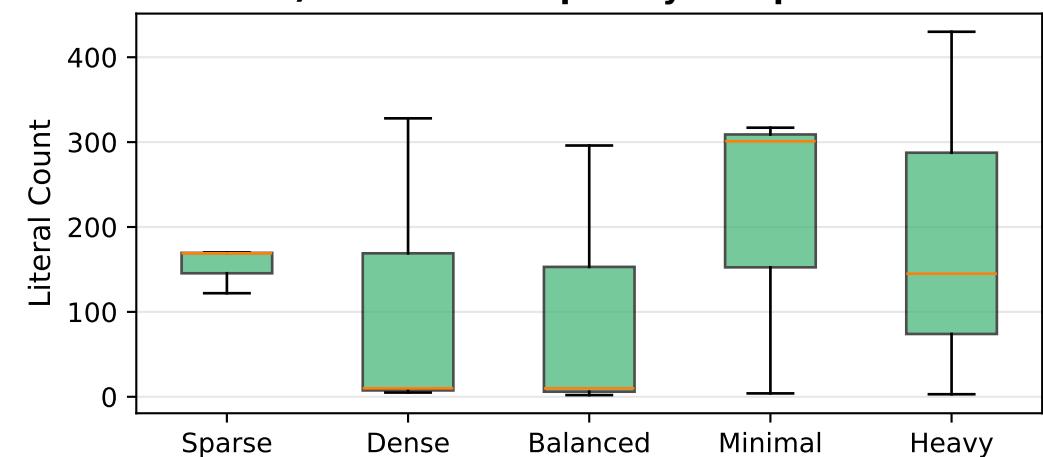
**A) Time Distribution Comparison**



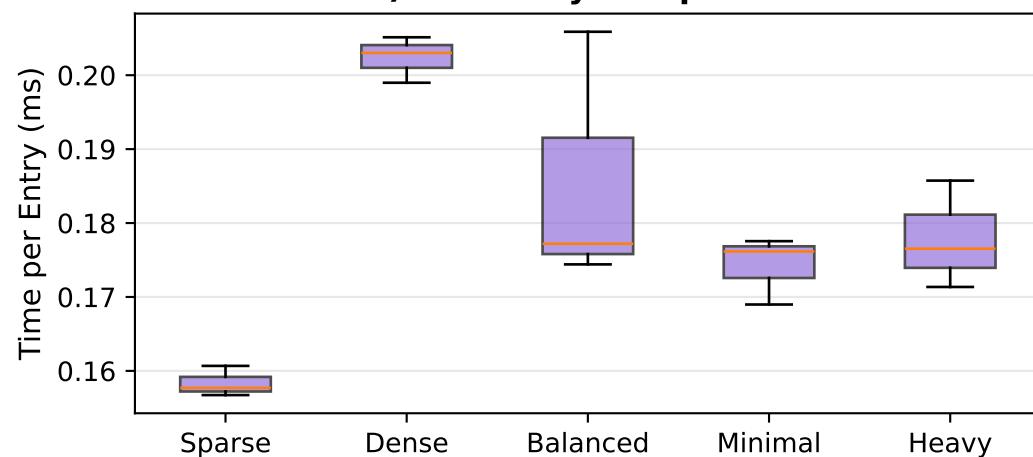
**B) Memory Distribution Comparison**



**C) Solution Complexity Comparison**



**D) Efficiency Comparison**



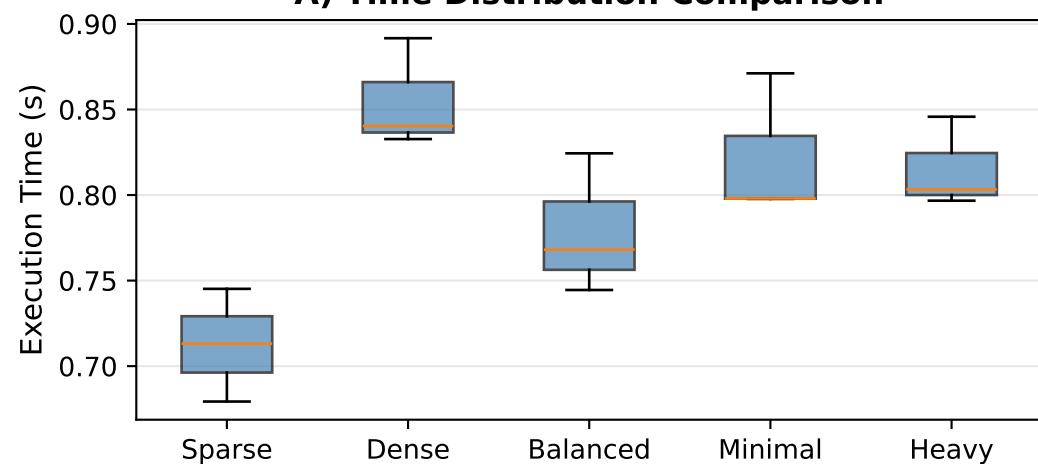
**E) Statistical Summary**

Distribution	N	Mean Time (s)	Std Time	Mean Mem (MB)	Mean Lits	Mean Terms
Sparse (20% 1s)	3	0.3243	0.0034	0.43	153.7	30.0
Dense (70% 1s)	3	0.4145	0.0052	0.05	114.3	27.7
Balanced (50% 1s)	3	0.3806	0.0291	0.00	102.7	22.0
Minimal DC (2%)	3	0.3568	0.0077	0.00	207.3	41.3
Heavy DC (30%)	3	0.3643	0.0122	0.00	192.7	34.7

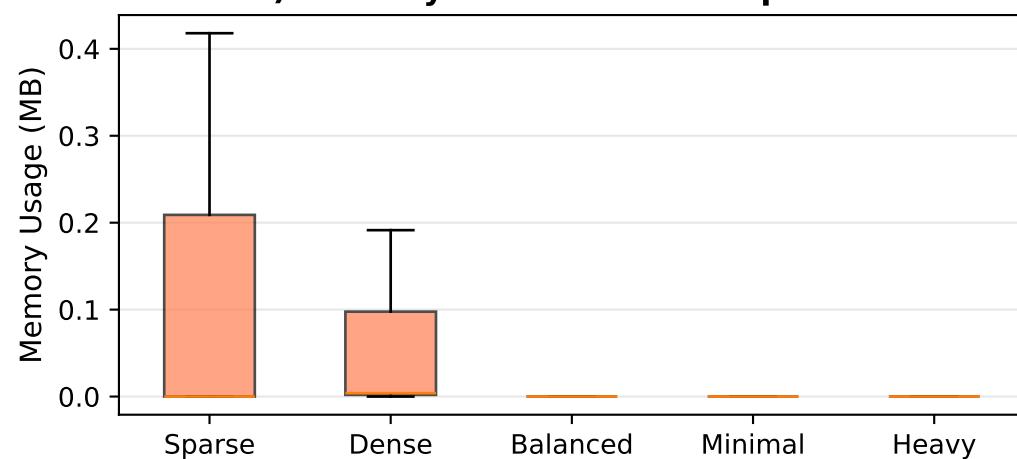
# 12-Variable Analysis: Distribution Performance

Truth Table Size:  $2^{12} = 4,096$  entries | Decay Study

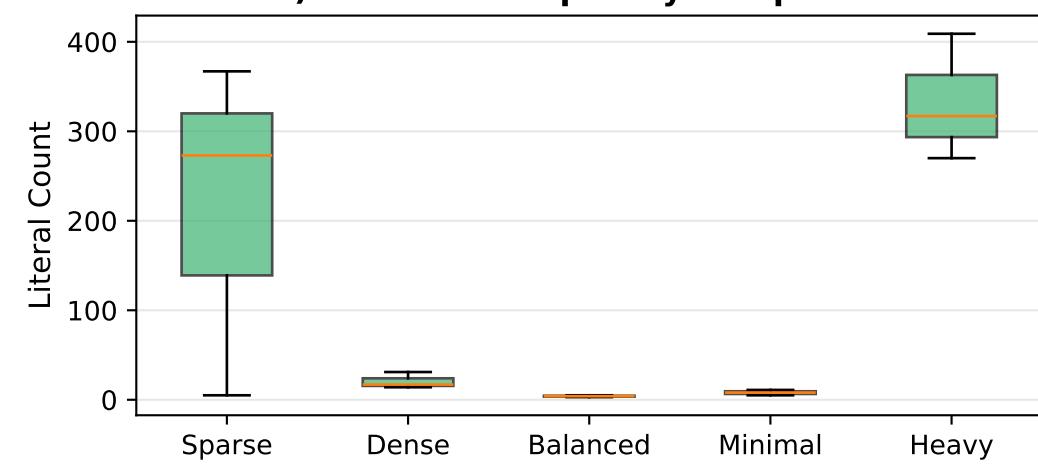
**A) Time Distribution Comparison**



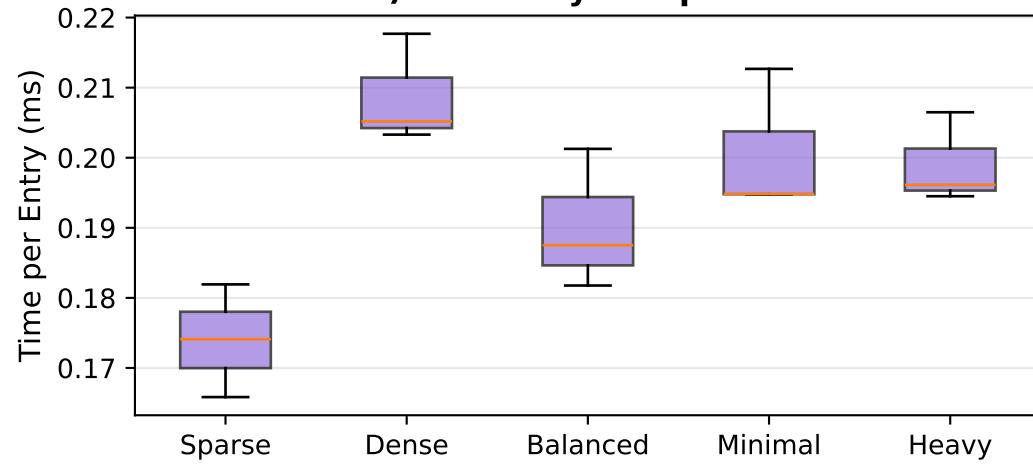
**B) Memory Distribution Comparison**



**C) Solution Complexity Comparison**



**D) Efficiency Comparison**



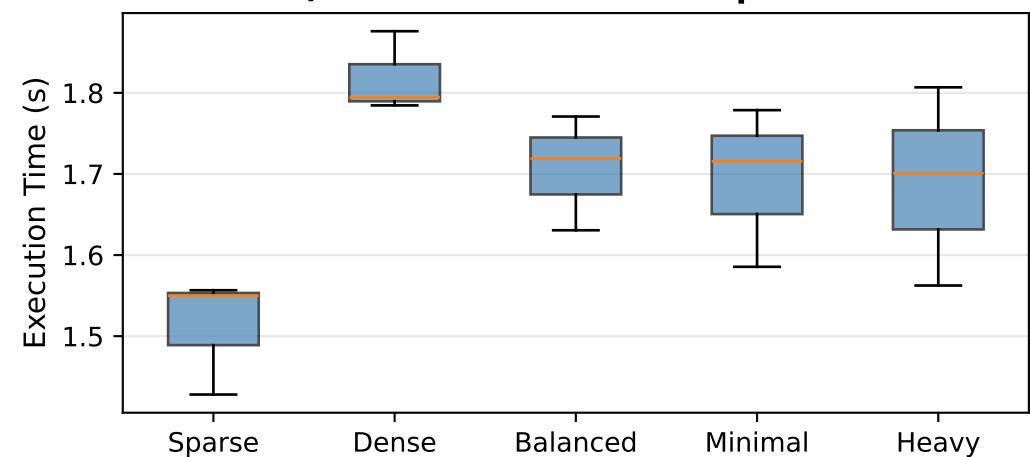
**E) Statistical Summary**

Distribution	N	Mean Time (s)	Std Time	Mean Mem (MB)	Mean Lits	Mean Terms
Sparse (20% 1s)	3	0.7125	0.0269	0.14	215.0	37.7
Dense (70% 1s)	3	0.8549	0.0262	0.07	20.7	4.7
Balanced (50% 1s)	3	0.7790	0.0335	0.00	4.0	1.0
Minimal DC (2%)	3	0.8223	0.0345	0.00	8.0	1.7
Heavy DC (30%)	3	0.8153	0.0217	0.00	332.0	62.3

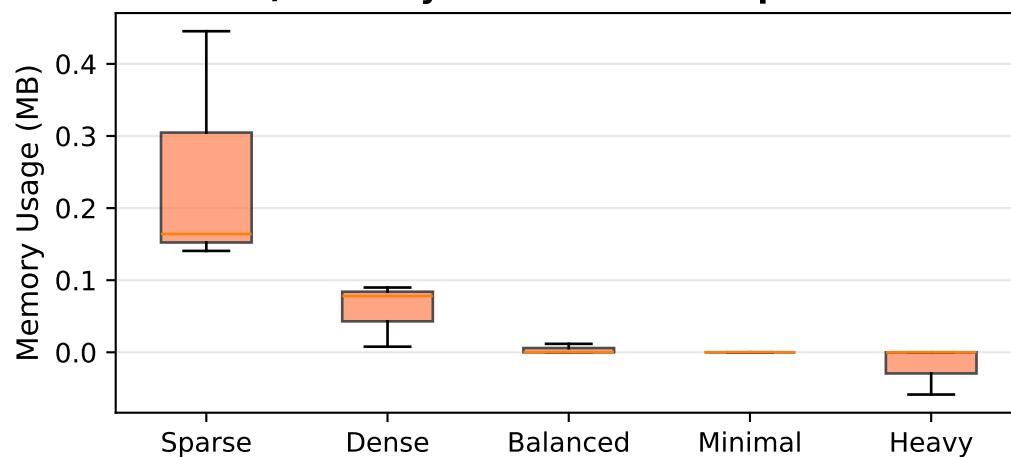
# 13-Variable Analysis: Distribution Performance

Truth Table Size:  $2^{13} = 8,192$  entries | Decay Study

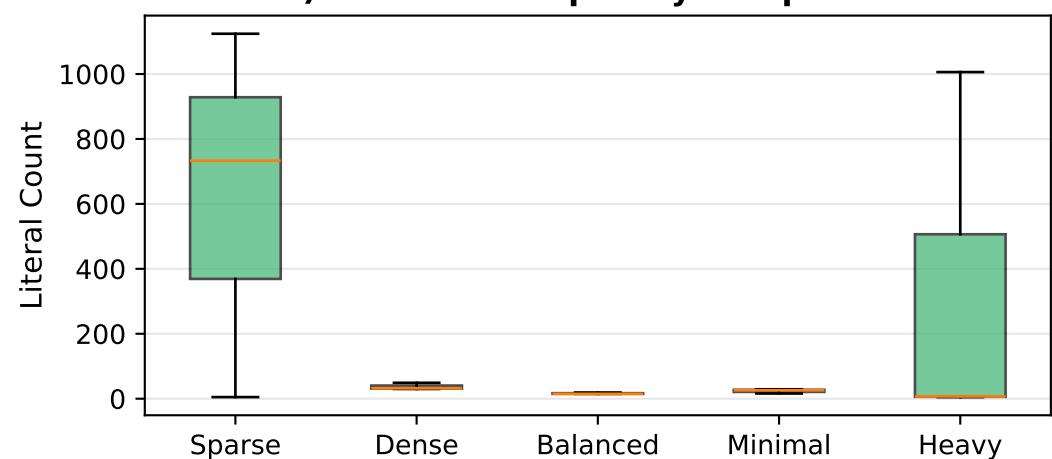
**A) Time Distribution Comparison**



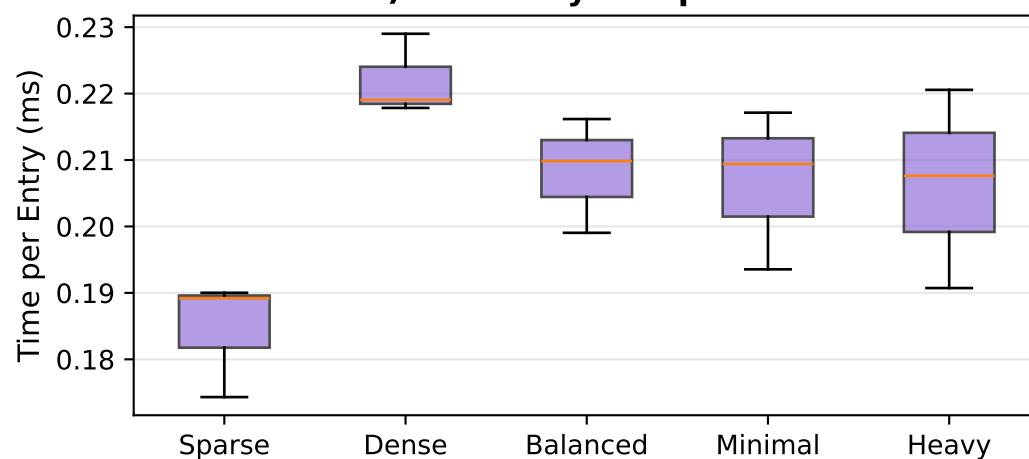
**B) Memory Distribution Comparison**



**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	1.5115	0.0591	0.25	620.7	97.3
Dense (70% 1s)	3	1.8184	0.0409	0.06	37.0	7.3
Balanced (50% 1s)	3	1.7068	0.0579	0.00	16.3	3.3
Minimal DC (2%)	3	1.6933	0.0804	0.00	23.7	4.0
Heavy DC (30%)	3	1.6900	0.1001	-0.02	339.3	55.7