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Friction Bloom — Dataset 002

# Technical Evaluation of Agent Adaptability: Systematic Grid-Friction Matrix Analysis at Scale

**Dataset 002 — 440 Experiment Runs**
Grid Sizes 5x5 through 15x15
Four Friction Modalities — 10 Repetitions Per Combination
Automated Batch Execution — Greedy Agent

## 1. Introduction and Methodological Framework

**Dataset 002 represents a systematic expansion of the Friction Bloom research program. Where Dataset 001 established baseline behavioral thresholds across 40 manually conducted experiments, Dataset 002 deploys an automated batch execution framework across a complete grid-friction matrix — 11 grid dimensions, 4 friction modalities, and 10 repetitions per combination — for a total of 440 controlled experiment runs.**

**The central research question remains consistent with Dataset 001: how do controlled spatial perturbations force autonomous agents into emergent adaptive behavior, and what structural properties of those perturbations determine whether the outcome is Bloom, Stable, Noise, or Collapse?**

**Dataset 002 introduces two advances over the prior work. First, the systematic matrix design eliminates sampling bias — every grid-friction combination is tested with equal statistical depth. Second, the scale of 440 runs produces statistically robust outcome distributions that reveal behavioral patterns invisible at 40 runs.**

### Metric Framework

**The four-metric evaluation framework from Dataset 001 is maintained without modification:**

- Bloom Score: Composite quantitative index of emergent path quality. Functional floor of 2.0 for all Stable outcomes. Scales toward 4.0 in high-performance adaptations.
- Novelty: Spatial divergence between baseline and perturbed path. Scores above 0.35 signal global route reconfiguration. Scores below 0.10 indicate the friction failed to meaningfully alter agent behavior.
- Coherence: Algorithmic consistency. Standard value of 2.0 maintained across all outcomes, indicating logically grounded movement even under high friction.
- Chaos: Non-functional or erratic kinematic behavior. In successful Bloom states, Chaos is maintained at 0.0 — purposeful adaptation, never stochastic.

### Experimental Scope

**The simulation environment scales from 5x5 to 15x15 in unit increments, producing 11 distinct grid dimensions. Agents were subjected to the same four friction perturbations established in Dataset 001: add_wall_gap_constraint, block_first_third, add_scatter_obstacles, and block_baseline_midpoint. Each grid-friction combination was run 10 times to produce stable outcome distributions.**

## 2. Global Outcome Distribution

**Across 440 total runs, the dataset produced the following outcome distribution:**

| Outcome | Run Count | Percentage | Interpretation |
|---|---|---|---|
| Bloom | 200 | 45.5% | Agent recovered through novel viable route |
| Stable | 130 | 29.5% | Friction did not meaningfully alter behavior |
| Noise | 110 | 25.0% | Behavior changed but adaptation was weak |
| Collapse | 0 | 0.0% | No runs exceeded adaptive capacity |

**The 45.5% Bloom rate across all runs represents a substantial increase in measurable adaptability compared to the 40-run sample in Dataset 001. Critically, zero Collapse outcomes were recorded across 440 runs — the Greedy Agent never fully failed to reach the goal. This establishes an important baseline: under the four friction modalities tested, the agent's utility recovery always succeeds, even when the quality of that recovery varies from Noise to Bloom.**

## 3. Categorical Assessment of Friction Modalities

**The most significant finding in Dataset 002 is the emergence of two deterministic friction behaviors — one perfect Bloom inducer and one perfect Bloom suppressor — that hold across all tested grid sizes.**

### 3.1 add_wall_gap_constraint — Perfect Bloom Inducer

| Metric | Value |
|---|---|
| Bloom Rate | 100.0% (110/110 runs) |
| Avg Bloom Score | 3.9181 |
| Avg Novelty | 0.6394 |
| Avg Coherence | 2.0 |
| Avg Chaos | 0.0 |

**add_wall_gap_constraint achieved a 100% Bloom rate across all 110 runs. Every single experiment produced a successful global route reconfiguration. This is not a statistical tendency — it is a deterministic behavioral property of the friction type.**

**The wall gap constraint functions as a topological bottleneck. Unlike friction types that place obstacles at specific path coordinates, the wall gap forces a macro-level deviation regardless of grid size. The agent cannot maintain its baseline L-shaped traverse when a wall bisects the environment at its midpoint. It must discover the gap and route through it — a structural compulsion to adapt rather than a probabilistic disruption.**

**The consistency of Avg Novelty at 0.6394 and Avg Bloom Score at 3.9181 across all grid sizes demonstrates scale invariance. This friction type's effectiveness does not degrade as the search space expands, a critical property for training data generation at larger scales.**

### 3.2 block_baseline_midpoint — Perfect Bloom Suppressor

| Metric | Value |
|---|---|
| Bloom Rate | 0.0% (0/110 runs) |
| Avg Bloom Score | 2.3368 |
| Avg Novelty | 0.1123 |
| Avg Coherence | 2.0 |
| Avg Chaos | 0.0 |

**block_baseline_midpoint achieved a 0% Bloom rate across all 110 runs. Not a single experiment produced a Bloom outcome. This is the exact inverse of add_wall_gap_constraint — a deterministic Bloom suppressor.**

**The technical explanation lies in the geometric nature of the disruption. The midpoint block is localized at a single coordinate in the middle of a long horizontal traverse. The agent performs a minimal local deviation — a single-step adjustment — rather than a global route reconfiguration. The disruption is too narrow to force the agent out of its baseline behavioral strategy. Novelty consistently registers below 0.15, well below the 0.35 threshold required for Bloom classification.**

**This finding has direct implications for experimental design. Including block_baseline_midpoint in future run sets as a control condition provides a reliable Stable-outcome baseline against which higher-impact frictions can be compared.**

## 3.3 block_first_third — Probabilistic Bloom Generator

| Metric | Value |
|---|---|
| Bloom Rate | 45.5% (50/110 runs) |
| Avg Bloom Score | 3.0623 |
| Avg Novelty | 0.3541 |
| Avg Coherence | 2.0 |
| Avg Chaos | 0.0 |

**block_first_third produces Bloom outcomes in exactly 45.5% of runs — an intermediate behavior that reflects the geometric tension between blockage and gap efficiency. When the block forces a significant early deviation, the agent produces a genuine Bloom. When the agent finds a minimal local route around the block, the result is Noise.**

**The Avg Novelty of 0.3541 sits precisely at the Bloom threshold, confirming that this friction type operates in a boundary regime between global and local adaptation. Its probabilistic nature makes it valuable for generating training data that captures the transition between outcome states.**

## 3.4 add_scattered_obstacles — Scale-Dependent Behavior

| Metric | Value |
|---|---|
| Bloom Rate | 36.4% (40/110 runs) |
| Avg Bloom Score | 2.6023 |
| Avg Novelty | 0.2008 |
| Avg Coherence | 2.0 |
| Avg Chaos | 0.0 |

**add_scattered_obstacles confirms the scale-dependence finding from Dataset 001 with far greater statistical confidence. At smaller grid sizes (5x5, 6x6), scattered obstacles achieve Bloom by forcing global route deviation. At larger sizes (10x10 and above), the obstacle density decreases relative to the square of the grid dimension, allowing the agent to bypass disruptions without meaningful adaptation.**

**The Avg Novelty of 0.2008 — below the 0.35 Bloom threshold — reflects this degradation. While the friction produces Bloom at small scales, its aggregate effectiveness is suppressed by large-scale Stable outcomes.**

## 4. Grid Scaling Analysis — The 10x10 Threshold

**The Bloom Rate by Grid Size data reveals a critical behavioral transition at the 10x10 boundary:**

| Grid Size | Bloom Rate | Avg Bloom Score | Behavioral Pattern |
|---|---|---|---|
| 5x5 | 75.0% | 3.2593 | High adaptability — dense friction effect |
| 6x6 | 75.0% | 3.3839 | High adaptability — strong structural forcing |
| 7x7 | 50.0% | 2.8621 | Transition — mixed outcomes begin |
| 8x8 | 50.0% | 3.1960 | Transition — structural frictions still dominant |
| 9x9 | 75.0% | 3.2865 | Anomalous recovery — wall gap dominance |
| 10x10 | 25.0% | 2.8180 | Threshold — scattered obstacles lose utility |
| 11x11 | 25.0% | 2.7921 | Post-threshold stability — degraded adaptability |
| 12x12 | 50.0% | 2.8157 | Wall gap recovers bloom rate partially |
| 13x13 | 25.0% | 2.7942 | Large-scale Stable dominance |
| 14x14 | 25.0% | 2.7754 | Large-scale Stable dominance |
| 15x15 | 25.0% | 2.7955 | Large-scale Stable dominance |

**The data reveals a clear behavioral transition at the 10x10 grid boundary. Below 10x10, Bloom rates average 65%. At 10x10 and above, they drop to an average of 29% and stabilize. This transition marks the point at which scattered obstacles lose their disruptive power — their density becomes insufficient relative to the search space to**

force global route reconfiguration.

The 9x9 anomaly (75% Bloom rate, highest avg score) warrants further investigation. This may reflect an optimal geometric relationship between the wall gap position and the grid dimensions at that scale, producing near-maximum forcing conditions.

The 12x12 partial recovery (50% Bloom rate) similarly suggests that at specific grid scales, the wall gap constraint geometry realigns favorably with agent pathfinding strategy. These scale-specific phenomena represent productive targets for Dataset 003 investigation.

# 5. Implications for VectorLLM Training Pipeline

Dataset 002 produces 440 labeled behavioral sequences — each containing grid configuration, friction type, full baseline path coordinates, full altered path coordinates, and outcome classification. This structured dataset directly supports the VectorLLM training pipeline in three ways:

## 5.1 Deterministic Anchor Points

The 100% Bloom rate of add_wall_gap_constraint and the 0% Bloom rate of block_baseline_midpoint provide clean deterministic training signal. These 220 runs (110 per friction type) establish unambiguous behavioral poles — maximum adaptability and minimum adaptability — that the model can use as anchors for outcome prediction.

## 5.2 Transition State Training Data

The 110 runs from block_first_third, operating at the Bloom threshold, provide training data that captures the behavioral boundary between global and local adaptation. This transition-state data is valuable for training models to distinguish genuine Bloom from Noise — a classification task that requires understanding the geometric relationship between path deviation and adaptation quality.

## 5.3 Path Sequence Data

Unlike Dataset 001, which was documented without full path coordinate sequences, Dataset 002 captures the complete baseline and altered path arrays for every run. These coordinate sequences can be used to train models on spatial reasoning — specifically, how an agent's path geometry changes in response to environmental constraints. This is the foundational data type for behavioral sequence modeling.

# 6. Conclusion: Synthesized Findings

Dataset 002 establishes four primary conclusions that extend and deepen the Dataset 001 findings:

### Scale-Invariant Stressor Confirmed

add_wall_gap_constraint is a perfect Bloom inducer across all tested grid dimensions. Its 100% Bloom rate at 440-run scale confirms the Dataset 001 hypothesis that structural bottlenecks function as scale-invariant adaptability stressors. This friction type is the recommended primary stressor for all future Friction Bloom experimental designs.

### Perfect Control Condition Identified

block_baseline_midpoint produces zero Bloom outcomes across all tested conditions. Its deterministic Stable behavior makes it an ideal experimental control — a baseline against which the adaptability-inducing power of other friction types can be precisely measured.

### The 10x10 Adaptability Threshold

A consistent behavioral transition occurs at the 10x10 grid boundary. Below this threshold, Bloom rates average 65% and scattered obstacles remain effective. Above it, Bloom rates stabilize at approximately 25%, driven primarily by wall gap constraint alone. Future dataset design should treat 10x10 as a structural boundary — small-scale and large-scale experiments represent qualitatively different behavioral regimes.

### Dataset 003 Targets

Two phenomena identified in Dataset 002 warrant targeted investigation: the 9x9 Bloom anomaly and the 12x12 partial recovery. Both suggest scale-specific geometric relationships between friction placement and agent pathfinding strategy that are not captured by the current experimental design. Dataset 003 should isolate these scales with higher repetition counts (25-50 reps per combination) to characterize these behaviors precisely.