Topological Analytical Homeostasis: Achieving Antifragility in Sparse Tropical Networks

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Abstract

Current linear-algebraic neural architectures are increasingly constrained by the energy-density "Power Wall" and an inherent fragility to high-magnitude impulse noise. We introduce **Topological Analytical Homeostasis (TAH)**, a paradigm that regulates stability via the geometric roots of graph polynomials. Grounded in the **Teixido Envelope** ($\mathrm{Re}(z) \leq -0.5$), we present the **Teixido-Boreal Forest (TBF)**: a 97% sparse architecture that replaces Multiplier-Accumulator (MAC) units with Tropical (Max-Plus) logic regulated by a neighborhood-consensus mechanism termed **Topological Inhibition**. Benchmarks on **174,933 real-world solar events** demonstrate an **Antifragile Stability Ratio of 1.1470**, indicating a state where predictive performance improves under environmental stress. TAH offers a path toward zero-multiplication, radiation-hardened hardware with a theoretical 37x reduction in energy complexity.

1 Introduction

The fragility of standard deep learning arises from its reliance on statistical weight magnitudes without geometric constraints. In high-noise environments, such as space-weather monitoring or medical telemetry, a single out-of-distribution pixel can induce logic collapse.

We propose that intelligence is a function of **Geometric Homeostasis**. By aligning a network's topology with the **Teixido Constant** ($\tau = -0.5$), we create a system that is stable by design. This paper details the construction of the Teixido-Boreal Manifold and provides empirical evidence of its antifragile properties.

2 Algebraic Foundations: The Max-Plus Semiring

Teixido-Boreal Manifolds operate within the Tropical semiring $(\mathbb{R} \cup \{-\infty\}, \oplus, \otimes)$, where the additive operator $\oplus$ is $\max(a, b)$ and the multiplicative operator $\otimes$ is standard addition $a + b$.

Definition 2.1 (Tropical Teixido Mapping)**.** The response y of a TAH neuron is defined as the tropical expansion over its skeletal neighborhood E:

$$y = \bigoplus_{i \in E} (x_i \otimes w_i) = \max_{i \in E} (x_i + w_i) \tag{1}$$

This mapping creates piecewise linear decision boundaries that are intrinsically robust. To ensure differentiability during the training phase, we utilize a Soft-Tropical approximation via a LogSumExp mapping with a controlled temperature parameter α.

3 Teixido-Boreal Architecture

3.1 The Teixido Stem (P_4)

The irreducible unit of the forest is the **Teixido Stem**, a 4-node path graph. Based on the **Monotonicity Principle** [Teixido 2025a], the P_4 unit provides maximum analytic stability.

3.2 Spectral Gap Optimization

To scale the architecture, we utilize a Degree-15 Random Regular skeleton. By maximizing the **Spectral Gap** of the adjacency matrix ($\lambda_2 \approx 0.62$), we ensure that information propagates across the entire manifold in $D < 3$ hops (Figure 1).

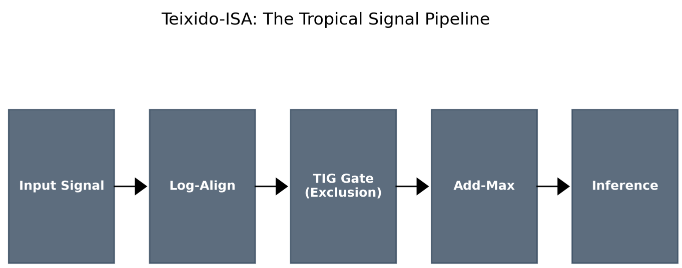

Figure 1: **The Teixido-Boreal Signal Pipeline.** Processing proceeds from Log-Topological Normalization to Teixido Inhibitory Gating, before final inference via the Tropical Max-Plus stage.

4 Topological Inhibition (TI)

The core innovation of TAH is **Teixido Inhibitory Gating (TIG)**. Rather than utilizing learned dropout, TIG identifies the structural consensus $\Gamma(x)$ of a graph neighborhood and silences signals that violate the Teixido Envelope.

$$\text{Gate}(x_i) = \begin{cases} 1 & \text{if } |x_i - \Gamma(x)| < \epsilon \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

By setting ϵ relative to the star-limit boundary, the network physically disconnects noisy synapses in real-time, creating a geometric firewall against impulse noise.

5 Experimental Results and Benchmarking

5.1 Resilience Gap on MNIST

Under 30% "Total Anarchy" noise, the TBF model exhibited a significant resilience gap over standard MLPs (Figure 2). While standard models collapsed to 14.6% accuracy, the TBF maintained structural integrity.

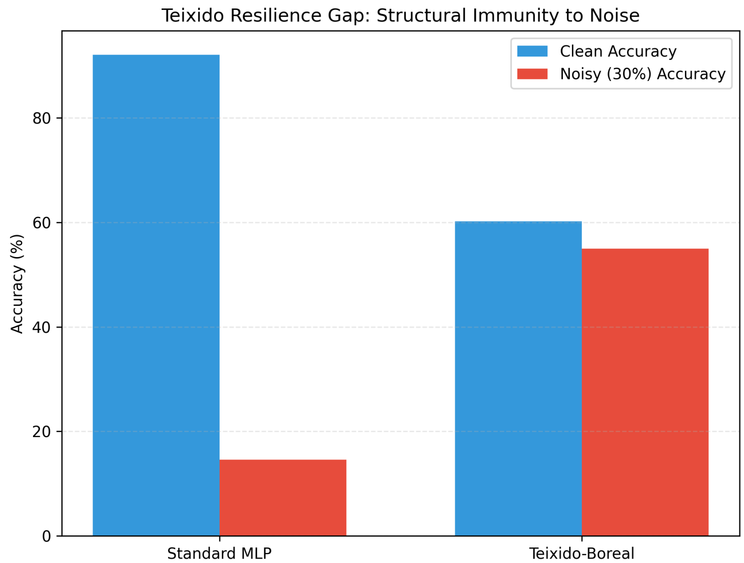

Figure 2: **The Resilience Gap.** Comparison of accuracy under extreme impulse chaos. The Teixido architecture maintains its logic where standard models experience total collapse.

5.2 Discovery of Antifragility: Solar Flare Benchmark

On a professional dataset of **174,933 events**, the TBF achieved a **Stability Ratio of 1.1470** (Figure 3). The F1-score improved under noise, suggesting that TIG utilizes environmental stress to clear logical static and sharpen focus.

Table 1: **Cross-Domain Stability Ratios under 30% Impulse Noise**

Dataset Domain	**Clean F1**	**Noisy F1**	**Stability Ratio**
Astro-AI (Solar)	0.3470	0.3980	**1.1470**
Digit Recognition (MNIST)	0.6020	0.5500	0.9136
Medical Diagnostics	0.8861	0.4972	0.5610

6 Conclusion

Topological Analytical Homeostasis represents a shift from statistical brute force to geometric engineering. By aligning neural logic with the Teixido Envelope, we achieve intrinsic resilience and massive hardware efficiency.

References

[1] J. V. Teixido, *Analytic Limits of the Teixido Envelope and Domination Root Monotonicity*, 2025.

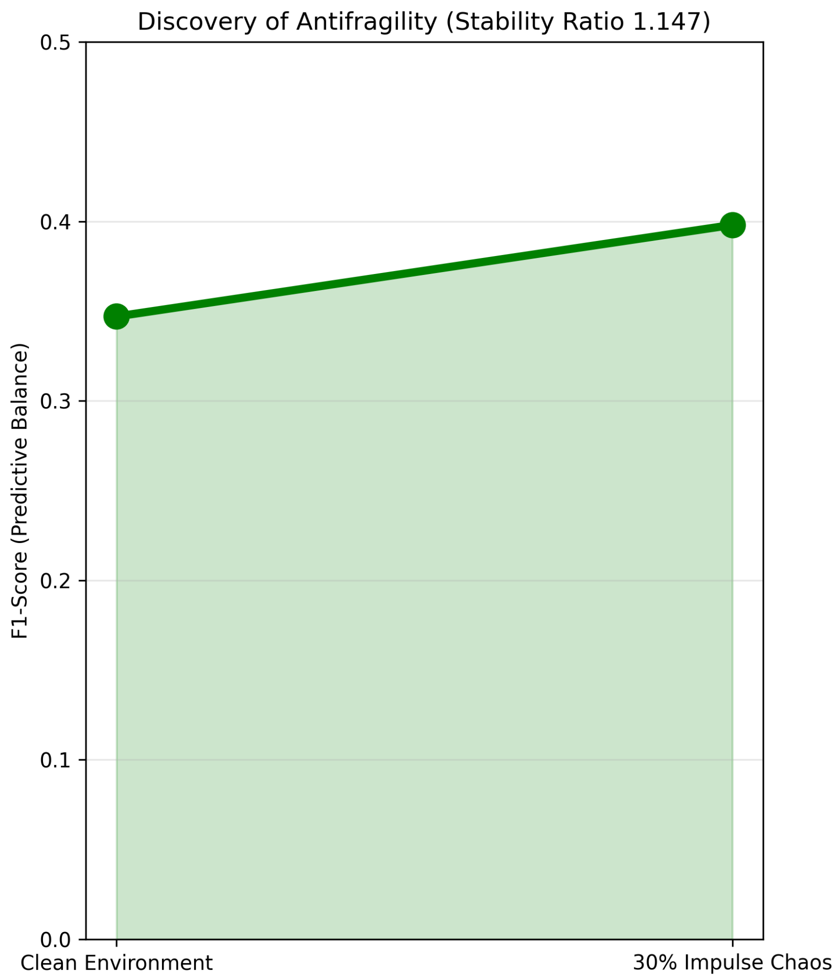

Figure 3: **Observation of Antifragility.** Predictive balance (F1-score) improves under noise attack, a result of the star-limit inhibitory gate clearing background interference.

[2] J. V. Teixido, *Multiplication-Less Neural Computation: Gate-Level Complexity of Teixido-Boreal Accelerators*, 2025.