AXIOM: A Cognitive Symbolic Dynamics Framework for Interpretable, Neuro-Inspired Decision Systems

Abstract: AXIOM is a recursive symbolic cognitive architecture that models interpretive decision-making using neuro-inspired dynamics. It bridges symbolic phase coherence with biologically plausible accumulator models to enable interpretable, adaptable, and context-sensitive AI cognition.

System Overview

AXIOM is built as a symbolic lattice where each node represents an interpretive frame updated recursively over time. The system integrates symbolic superposition, phase drift dynamics, and feedback loops modeled on cognitive dissonance and alignment. Key metrics like Coherence Ratio (C_r), Conflict Penalty (P_c), and interpretive phase (θ) define state transitions and learning feedback.

Core Mechanisms

- Symbolic Superposition: Weighted symbolic tokens fused per interpretive context. - Conflict Penalty (P_c): Accumulates symbolic tension driving instability. - Coherence Ratio (C_r): Tracks alignment between symbolic frames and cognitive state. - Phase Feedback: $\theta_{t+1} = \theta_t + \omega - \beta \cdot P_c$ dynamically modulates symbolic coherence. - Decision Lattice: Symbolic states expressed via .mod classes — coherent, conflicted, or neutral.

LCA Integration

AXIOM integrates the Leaky Competing Accumulator (LCA) model per node: - Dual accumulators (coherent/conflicted) update via gain, leak, inhibition, and noise. - Symbolic state is switched based on threshold crossing with winner-take-all dynamics. - Real-time confidence estimated as |acc_coherent - acc_conflicted| for interpretability.

Grid Simulation Engine

An interactive N×N grid of `.symbol` nodes represents AXIOM's symbolic field: - Each node updates its symbolic state using LCA logic. - Visual interface encodes state with color: green (coherent), red (conflicted), gray (neutral). - Live tooltips show accumulator values, confidence, and time since last state switch. - Control Panel includes sliders for tuning gain, inhibition, leak, noise, and threshold.

Comparative Theory

AXIOM extends classical dynamical system theory (e.g., Axiom A) into symbolic cognition: - Conflict dynamics analogous to entropy. - Symbolic coherence as a topological attractor. - LCA and SLCA neural accumulator models provide the biomimetic engine beneath symbolic decisions.

Applications

- Adaptive HCI: Interfaces reacting to symbolic ambiguity and conflict. - Explainable AI: Symbolic overlays for tracing LLM decision confidence and dissonance. - Cognitive Modeling: Simulating interpretive frame switching and internal conflict. - Robotics: Real-time decision layers interpretable as symbolic state lattices.

Future Directions

- Spatial LCA: Node-to-node inhibition modeling semantic neighborhoods. - Distributed Symbolic Fields: Emergent global attractor states. - Integration with LLMs for stable semantic memory fusion. - Modular API embedding for real-world AI agents.