Criticality, Phase Transitions, and the Emergence of Meaning: A Dynamical Perspective on Value in Hyper-Aether Systems

Abstract

We propose a unified dynamical framework for understanding meaning, concept formation, and creativity in AI-native computational systems. Building on the Hyper-Aether architecture, we interpret the value function $V(G)$ over graph-structured computational states as an energy landscape governing system dynamics. We show that (1) meaning corresponds to stable attractors, (2) concept formation corresponds to phase transitions, and (3) creativity emerges from critical fluctuations near phase boundaries. This framework connects reinforcement learning, statistical physics, and semantic computation into a single theoretical model.

1 Introduction

Recent AI systems challenge classical views of computation by integrating learning, adaptation, and semantic interpretation. In the Hyper-Aether framework, computation is described as the evolution of graph-structured states:

$$G_{t+1} \sim \Phi(G_t, \eta_t), \tag{1}$$

where G is a computational graph and η_t represents stochasticity.

We extend this framework by introducing a value function:

$$V(G), \tag{2}$$

which evaluates the semantic significance of structures.

This paper develops a physical interpretation of $V(G)$ as an energy landscape and explores its implications for meaning, concept formation, and creativity.

2 Meaning as Energy Minimization

We interpret value as the negative of an energy function:

$$V(G) \sim -U(G). \tag{3}$$

Under this mapping:

- High value $\leftrightarrow$ low energy
- Stable meaning $\leftrightarrow$ local minima

Thus, meaning corresponds to attractors:

$$G^* = \arg\max V(G). \tag{4}$$

3 Bistability and Ambiguity

A simple model of semantic ambiguity is given by a double-well potential:

$$U(x) = ax^4 - bx^2. \tag{5}$$

This system exhibits two stable states, corresponding to two meanings. The system state transitions between these attractors depending on noise and context.

Thus:

- Multiple meanings $\leftrightarrow$ multiple minima
- Disambiguation $\leftrightarrow$ symmetry breaking

4 Concept Formation as Phase Transition

We model concept formation as a phase transition in the value landscape.

Consider a parameterized potential:

$$U(x) = x^4 - \mu x^2. \tag{6}$$

- $\mu < 0$: single minimum (no concept)
- $\mu > 0$: two minima (concept differentiation)

At $\mu = 0$, the system undergoes a bifurcation.

We define concept formation as:

$$\exists G^* \text{ such that a new stable attractor emerges.} \tag{7}$$

This corresponds to symmetry breaking and the emergence of structured meaning.

5 Critical Fluctuations and Creativity

Near the critical point, systems exhibit large fluctuations:

- increased sensitivity
- long-range correlations
- metastable transitions

We interpret this regime as the source of creativity.

Let:

$$G_{t+1} \sim \Phi(G_t, \eta_t), \tag{8}$$

where η_t controls stochasticity.

- $\eta \to 0$: rigid, no exploration
- $\eta \to \infty$: random, no structure
- $\eta \approx \eta_c$: critical regime

Creativity emerges when the system:

- explores multiple structures (variation)
- selects high-value configurations (selection)

We propose a creativity measure:

$$C = \mathrm{Var}(G_t) \cdot \Delta V, \tag{9}$$

capturing both structural change and value improvement.

6 Insight as Phase Transition

We interpret insight as a rapid transition between attractors:

$$G_t \to G^*_{\text{new}}. \tag{10}$$

This corresponds to:

- barrier crossing
- sudden stabilization
- qualitative change in representation

7 Discussion

This framework suggests:

- Meaning = stable structures in $V(G)$
- Concepts = phases of the system
- Learning = deformation of the energy landscape
- Creativity = critical exploration

It connects:

- reinforcement learning (value functions)
- statistical physics (phase transitions)
- cognitive science (concept formation)

8 Conclusion

We have presented a dynamical interpretation of meaning and cognition in AI systems. By treating value as an energy landscape over graph structures, we unify:

- semantic stability (attractors)
- concept formation (phase transitions)
- creativity (critical fluctuations)

This perspective suggests that intelligent systems operate near criticality, where structure and variability coexist, enabling the emergence of new meaning.